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GREEN INDUSTRIAL POLICY:

CONCEPT, POLICIES, COUNTRY EXPERIENCES

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FOREWORD

A green economy is increasingly accepted as a key driver in tackling climate change, poverty, pollution, health and any number of critical goals to improve life for this planet and its people. Bold words, but this report shows that it is within our grasp to turn them into action.

Restructuring industrial systems needs a diverse, cross-sector approach. By moving beyond traditional industrial policies to a framework that encompasses environmental and energy policies, the authors explore how this could accelerate structural transformation and enhance productivity. In fact, through research and case studies, it shows how green industrial policy frameworks can be a valuable tool for all economies.

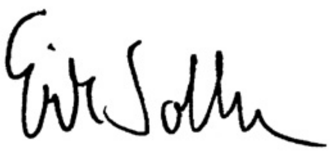
For example, Morocco used to import 95 per cent of its energy via coal, gas and electricity in 2011. Now, around a third is from domestic renewable sources and the country is building Africa's largest solar power plant, the Ouarzazate Solar Complex. The country plans to produce 15 per cent of electric capacity from solar power by 2020. As well as boosting Morocco's renewable energy, the solar plant is also strengthening the local economy. People like the 35-year-old Azzedine, who works as a driver, found jobs there. For the first time, he now earns a fixed salary every month and feels lucky to be among the young people with a stable job at the plant. However, it is not only big projects that will bring about economic and environmental benefits. The demand for small independent electricity producers may also promote long-term jobs and private sector development.

Likewise, in China, unbearable urban air pollution has led to health problems, which are in turn driving an increase in demand for electric mobility. It's a demand being carefully nurtured through a basket of measures including research and development, technology sharing agreements with global investors, strategic public procurement, purchase subsidies and city trials. Not only do emissions go down, but in 2014, China was already producing 85 per cent of the world's electric

two-wheelers and exporting some 5 million a year, mainly to other Asian markets.

Many of the findings of this report are already being put into practice around the world. Through the United Nations Industrial Development Organization, the Partnership for Action on Green Economy is helping governments to develop action plans that include green industrial policy recommendations. For example, in Burkina Faso, Ghana, Peru, Senegal and China green industry assessments have been conducted or are under way.

Green industrial policies offer a practical way to shape inclusive, sustainable economies right around the world. I sincerely hope that this report will raise awareness of the tools available to public and private decision-makers determined to build a better future for this planet and its people.



ERIK SOLHEIM
Head of UN Environment

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ABBREVIATIONS

ACEA	European Automobile Manufacturers' Association
ADB	Asian Development Bank
ADEREE	National Agency for the Development of Renewable Energy Sources and Energy Efficiency Morocco
ANP	Brazilian National Agency of Petroleum, Natural Gas, and Biofuels
ANPME	Moroccan National Agency for the Promotion of Small and Medium-sized Enterprises
BAFU	Swiss Federal Office for the Environment
BEE	Indian Bureau of Energy Efficiency
BLS	U.S. Bureau of Labor Statistics
BMF	Austrian Federal Ministry of Finance
BMU/ BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
BNDES	Brazilian Development Bank
BNEF	Bloomberg New Energy Finance
BNSTP	Bourse Nationale de Sous-traitance et de Partenariat
CDM	Clean Development Mechanism
CEEW	Council on Energy, Environment and Water
CGEE	Brazilian Centre of Strategic Management and Studies
CIDE	Brazilian fuel tax
COFINS	Brazilian Social Security Financing Contribution
COMETR	Competitiveness Effects of Environmental Tax Reforms
CO_2e	Carbon dioxide equivalents
DENA	German Energy Agency
DIE	German Development Institute
DIHK	German Chamber of Industry and Commerce
EGSS	Environmental Goods and Services Sector
EU	European Union
EZ	Dutch Ministry of Economic Affairs
FAO	Food and Agriculture Organization of the United Nations
FINEP	Brazilian Studies and Projects Financing Agency
GATS	General Agreement on Trade in Services
GATT	General Agreement on Tariffs and Trade
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GGGI	Global Green Growth Institute
GHG	Greenhouse gas
GPA	Agreement on Government Procurement
GW	Gigawatt
HCS	High-carbon sector
IAA	Brazilian Institute of Sugar and Alcohol
ICMS	Brazilian value added tax on sales and services
ICSID	International Centre for the Settlement of Investment Disputes
ICTSD	International Centre for Trade and Sustainable Development
IDR	Indonesian Rupiah
IEA	International Energy Agency
IESO	Ontario Independent Electricity Systems Operator
IFC	International Finance Corporation
IISD	International Institute for Sustainable Development
ILO	International Labour Organization
IMF	International Monetary Fund
INSG	International Nickel Study Group
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRESEN	Institut de Recherche en Energie Solaire et en Energies Nouvelles
ISL	International Synergies, Ltd.
ISO	International Organization for Standardization
LCS	Low-carbon sector
LDC	Least developed countries

LCR	Local content requirerment
LNP	Liquefied natural gas
LPG	Liquid petroleum gas
LULUCF	Land use, land-use change and forestry (greenhouse gas inventory sector)
MAD	Moroccan Dirham
MAP	German Market Incentive Programme for Renewable Energies
MASEN	Moroccan Agency for Sustainable Energy
MCINET	Moroccan Ministry of Industry, Trade and New Technology
MEMEE	Moroccan Ministry of Energy, Mining, Water and the Environment
MENA	Middle East and North Africa
MME	Brazilian Ministry of Mines and Energy
MW	Megawatt
NAFTA	North American Free Trade Agreement
NAPE	German National Action Plan on Energy Efficiency
NRDC	Natural Resources Defense Council
OECD	Organisation for Economic Cooperation and Development
OICA	International Organization of Motor Vehicle Manufacturers
OPA	Ontario Power Authority
PAGE	Partnership for Action on Green Economy
PAISS	Brazilian Support Plan for Industrial and Technological Innovation for the Sugar-Energetic and Sugar-Chemical Sectors
PERG	Moroccan Renewable Energy and Global Rural Electrification Project
PIS	Brazilian Profit Participation Programme
PROMASOL	Development Programme of the Moroccan market for solar water heaters
PROPER	Indonesia's Programme for Pollution Control, Evaluation, and Rating
RCREEE	Regional Center for Renewable Energy and Energy Efficiency
RREUSE	Reuse and Recycling EU Social Enterprises
SCM	Subsidies and Countervailing Measures
SEEA	System of Environmental-Economic Accounting
TEDA	Tianjin Economic-Technological Development Area
TISA	Trade in Services Agreement
TRIMS	Agreement on Trade-Related Investment Measures
TRU	Brazilian highways maintenance tax
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	UN Environment / United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICA	Brazilian Sugarcane Industry Association
UNIDO	United Nations Industrial Development Organization
VAT	Value added tax
VROM	Dutch Ministry of Housing, Spatial Planning and the Environment
WBCSD	World Business Council for Sustainable Development
WEF	World Economic Forum
WIEGO	Women in Informal Employment: Globalizing and Organizing
WIOD	World Input-Output Database
WITS	World Integrated Trade Solution
WHO	World Health Organization
WTO	World Trade Organization
WWII	Second World War
ZAR	South African Rand

EXECUTIVE SUMMARY

TILMAN ALTENBURG AND CLAUDIA ASSMANN

Humanity is confronted with profound and mounting man-made environmental crises. The United Nation's Millennium Ecosystem Assessment provided an alarming inventory of the degree of deterioration in many of the world's ecosystems (MEA 2005). Global warming is now widely recognised as an immediate threat to humanity. As the Intergovernmental Panel on Climate Change shows, only a few years are left to radically decarbonise the world economy if disastrous global warming is to be avoided (IPCC 2014). Other environmental crises have so far received less public attention, but are also serious and potentially threatening the continuity of human life on Earth. These include the loss of biodiversity, depletion of water reserves, ocean acidification and reduction of soil fertility, among others (Rockström et al. 2009).

Even in purely monetary terms–if we isolate nature's intrinsic value from the equation–the costs of environmentally unsustainable practices are enormous. The Lancet Commission on Pollution and Health estimates welfare losses due to environmental pollution at more than US$ 4.6 trillion per year, or 6.2 per cent of global GDP (Landrigan et al. 2017). The economic cost of global warming has been estimated at more than US$ 1.2 trillion per year, reducing the world's economic output by 1.6 per cent annually (DARA and the Climate Vulnerable Forum 2012). Various other, yet less visible, environmental threats may cause loss and damages in similar orders of magnitude. The dramatic reduction of population of bees and other insects so essential for pollinating crops, and thereby securing global harvests, is just one example.

A key underlying reason of all these negative trends is that the incentives that guide the way people invest, produce and consume are not accounting for environmental costs. Those are 'externalities' in the economic jargon. The need to rethink our incentive systems is thus obvious and urgent. Incentives need to be inspired by the principle of sustainability. They must be designed to ensure that environmental costs are internalized, pollution is kept to a minimum, material consumption is reduced, and inputs are reused or recycled to the greatest possible extent.

At the same time, there are social and economic challenges and aspirations. People want to live decent lives. Poverty is still widespread in many countries, and even in rich nations there are substantial clusters of poverty and unsolved problems of human development. Therefore, we need to tackle a dual challenge: To pursue economic development and wealth creation, particularly solving the problems of deprived segments of societies, while keeping resource consumption and pollution in accordance with Earth's biocapacity. Sharing prosperity more fairly is surely one part of the agenda. The other part, which is at the centre of this report, is to develop institutional and technological solutions that enable us to decouple economic development and human well-being from resource depletion and waste production. The benefits are obvious. Tackling the environmental problems that are causing millions of deaths and profound welfare losses today, and undermining the foundations for the development of future generations, will pay off for all of us.

Developing new institutions and technologies is a challenge for all countries. As the Global Footprint Network has shown, almost all countries that have achieved acceptable levels of human development–scoring 0.8 or higher on the Human Development Indicators, which is UNDP's threshold for high human development–did so by overstepping the world's biocapacity, whereas those countries that stayed within the Earth's limits so far invariably failed to provide the conditions for a high level of human development (Global Footprint Network 2010; UNEP 2011). Put differently, not a single country worldwide provides a role model for achieving decent human development sustainably within Earth's biocapacity. Just to emulate the development pathways of today's rich countries, assuming a linear development trajectory along which countries gradually evolve from underdeveloped to developed, has never been a convincing proposition, given countries' manifold and individual characteristics in terms of history, culture and geography. Once we start using sustainable development as a yardstick, it becomes even more obvious that development is not about 'catching up' with today's rich nations.

From this perspective, economic latecomers to the globalizing world economy even have an advantage. They can build their cities, their manufacturing industries, their energy and transport systems and their institutions in new, more sustainable ways that take their distinctive national characteristics into account. Surely, those countries that industrialised early had more time and better opportunities to accumulate wealth and develop institutions that may now help them cope with environmental challenges. However, latecomers are not as deeply locked into existing unsustainable infrastructures and century-old institutional routines that often hamper change in many ways.

In this report, we explore policy options for managing structural change that accounts for both the productivity and the environmental challenges in a harmonised way. We use 'green industrial policy' as our key concept. The term 'industrial policy' encompasses sets of measures that governments use to influence a country's economic structure in the pursuit of a desired objective.[1] Until very recently, this desired objective was first and foremost to enhance the productivity and competitiveness that in turn would allow for economic growth and higher incomes. However, as we have seen, looming environmental catastrophes–as well as other alarming trends related to poverty, inequity, exclusion and conflict–force us to reconsider the kind of structural change we want. The 2030 Agenda for Sustainable Development, adopted by the UN General Assembly in 2015, reflects a more encompassing perspective on the transformation of societies that balances economic, social and environmental objectives (UN 2015).

Our concept of green industrial policy starts from the assumption that we can learn a lot from several decades of experimenting with policies aimed at shaping economic structures in the pursuit of societal objectives. Many key principles of successful industrial policymaking can be derived, for example: the way entrepreneurial search processes can be channelled towards certain agreed societal objectives; how regulations, market-based instruments and financial incentives can be combined; how public services are delivered most effectively; and how mandatory and voluntary measures can be coordinated to achieve the best result. Applying these lessons to green industrial policy moves toward further specifics. These derive from the need to harmonise the requirements of productivity-enhancing structural change with environmental objectives and to align national interests with the protection of global commons. This has manifold practical implications. For example, certain economic transformations need to be accelerated to achieve results before ecosystems collapse and the original equilibrium cannot be restored. This calls for more proactive policy guidance to phase out harmful technologies and policies and to use both 'carrots and sticks' to speed up the dissemination of sustainable alternatives.

Our report aims to provide guidance to policymakers and practitioners as well as to contribute to the academic debate on green transformation strategies. It provides an up-to-date overview of the debate on green industrial policy, explores what countries can gain economically from pursuing environmental integrity, and what policy options are available to accelerate the transformation in ways that enhance well-being and environmental sustainability together. Practical examples are included in all chapters, and four national examples of successful green structural change are presented in detail, covering countries at very different levels of income and technological capacity.

The report has four parts. **PART 1** discusses the **conceptual foundations** of green industrial policy. Altenburg and Rodrik explain why looking through the lens of industrial policy provides important insights for a green transformation. They summarize lessons learned from decades of experimentation with, and research on, industrial policy and bring out key principles of smart policymaking that maximise the government's ability to overcome market failures while keeping the inherent risks of misallocation and political capture to a minimum. Subsequently, the authors identify six extra challenges of green transformations and explain the ways green industrial policy must go beyond the common practice of industrial policy in a business-as-usual setting.

PART 2, The economic and social co-benefits of green transformation, shows that green industrial policy may bring a number of economic and social co-benefits, in addition to environmental improvements. Padilla argues why, despite existing tradeoffs between growth policies and environmental protection, the idea of growing first and cleaning up later is not a good approach for policymakers and discusses what developing countries can gain from a green transformation. He identifies twelve ways in which developing countries can reap social and economic co-benefits of greening their economies. These range from better conditions for human health, preservation of resources for future growth, and avoidance of high switching costs in the future to immediate cost reductions through resource-efficient production and leveraging new competitive advantages through environmental goods and technologies.

Ambec then focuses on the firm level, describing how developing-country firms can gain competitive advantage through green policies. He shows

1 There is no uniform and generally agreed definition of 'industrial policy'. For an overview see Warwick (2013).

that, although environmental protection often comes at an additional cost to firms, it can also enhance their competitive advantages along four channels: product differentiation through green labels; development of new green products; productivity improvements that more than compensate for the costs of environmental protection; and knowledge spillovers in the innovation process.

Esposito, Haider, Semmler and Samaan explore how a green transformation can create employment benefits. Green transformation necessarily affects labour markets, creating new jobs in the environmental goods and services sector, but also reducing employment opportunities in sectors that are deliberately phased out due to their polluting effects. Measuring the net effects, however, is difficult because environmental improvements are incrementally adopted across sectors throughout transition and it is therefore impossible to draw a clear line between environmentally sound and polluting sectors and jobs. Also, it is difficult to attribute employment changes exclusively to environmental policies. With all these limitations in mind, there is evidence that what statistical authorities define as the environmental goods and services sector is increasing its employment share in most of the countries for which data exist.

PART 3, accelerating change, discusses some of the key policies that help to implement the green transformation. Given the urgent need to reduce some environmental pressures, proactive policies are needed to accelerate the replacement of unsustainable products and practices with green alternatives. Cosbey, Wooders, Bridle and Casier provide an overview of policy options to phase out environmentally harmful industries. Abandoning such industries is particularly challenging when the level of invested capital is high and there are strong linkages throughout national economies that create vested interests defending the status quo. To manage the transition to clean alternatives it is important to get public buy-in through consultations, combined with well-defined gradual timelines for change and support measures for those who are negatively affected. Societal acceptance is likely to be greater if the phase-out goes hand in hand with measures to develop environmentally sound substitutes.

Never and Kemp show how the phase-in of green alternatives can be accomplished. The challenge here is to cope with a variety of disincentives: the new green alternatives typically need to develop and become competitive in the face of established technologies that benefit from existing network effects and economies of scale, from path-dependent consumer behaviour and from political backing influenced by vested interest groups. Building on experiences from China, Germany, India and the Netherlands, the authors identify seven principles for the design of phase-in policies.

Schlegelmilch, Eichel and Pegels explore the rationale of environmental fiscal reforms and show how they need to be designed, particularly in developing countries, to achieve the dual purpose of protecting the environment and spurring competitiveness, industrial development and jobs. Differential taxation signals environmental costs while leaving it to competitive market forces to find the best technological and organizational solutions. Environmental fiscal reforms enhance the competitiveness of clean industries and reduce competitive advantages of polluting industries. Tax rates for enterprises exposed to international competition thus need to be designed carefully, and more efforts should be undertaken to harmonise environmental taxation internationally. Revenues can be used for poverty reduction, green infrastructure and other national priorities, and they can be channelled in a way that helps to build reform alliances and overcome resistance.

Balke, Evans, Averous Monnery and Rabbiosi show what is needed to shift from linear production systems in which a large part of the material inputs of production end up as waste to circular economies that reduce waste, reuse materials as much as possible and recycle the rest. Circularity is thus a key principle to decouple production from resource consumption and pollution. The authors discuss different circular economy approaches and provide an overview of key policy instruments. These range from eco-design guidelines that ensure convenience, longevity, repairability and recyclability and extend to the setup of waste collection systems and the promotion of resource-saving business models, such as sharing platforms. The authors argue that such policies need to be contextualized for different country conditions and they illustrate this with a series of examples including eco-industrial parks and nation-wide systemic solutions.

Cosbey then explores the ways in which green industrial policies might be restricted by international trade and investment law. Many industrial policy tools have trade-related aspects and these are regulated through a range of multi- and bilateral agreements with strong enforcement mechanisms. For example, tariff policy is strongly constrained by bound tariff rate commitments; subsidies and performance requirements conditional on domestic content requirements and export performance are prohibited. Yet, many other green industrial policy options are not affected by trade and investment law, such as feed-in-tariffs, performance requirements for training of staff, science and education policies, funded demonstration projects, and others. Procurement policies can be used to source greener products, yet not to discriminate in favour of domestic suppliers if governments are party to the WTO's plurilateral Government Procurement Agreement.

PART 4, country experiences, then examines the practical implementation of key policies in four countries at different levels of income and technological capacity: Morocco, China, Brazil and Germany. All examples address the simultaneous challenge of fostering jobs and technological learning and creating competitive advantages in new industries while greening their economies.

Vidican Auktor shows how Morocco uses its favourable conditions for energy generation from solar radiation and wind to reduce its enormous fuel import dependence, to create employment and to trigger technological learning. In 2011, the country was importing more than 95 per cent of its energy and its energy demand is expected to triple by 2030. Morocco's government not only encourages foreign direct investment in solar and wind energy projects but also supports related skills development and the emergence of domestic supplier industries. Moreover, policymakers foster both high-tech investments in concentrated solar power plants and low-tech rooftop solar thermal and photovoltaic projects to develop various segments of the labour market.

Altenburg, Feng and Shen provide an overview of China's policies to promote electric mobility with the dual aim of curbing urban air pollution and enhancing the competitiveness of its national automobile industry. That industry is strategic for China's technological upgrading, but it has not been able to reach the productivity levels of its international competitors so far. The shift to electric powertrains is therefore seen as an opportunity to boost national competitiveness by leapfrogging into a new generation of technologies. The government's comprehensive support package is unrivalled by any other country. Progress has been made in four areas of technology development: modern cars and buses, low-speed cars, two-wheelers and battery manufacturing.

Da Motta Veiga and Polónia Rios assess the role of policy in the emergence of the national bio-ethanol industry. Sugar cane cultivation and the industrial transformation of sugar into ethanol have received strong backing since the 1970s to replace gasoline consumption and decrease dependence on oil imports. More than 15 per cent of Brazil's energy demand is covered by ethanol, contributing to the country's low-carbon footprint. The authors argue that the alleged direct negative effects on Brazil's forest cover are largely unfounded, although some indirect effects may exist. High-yielding second generation sugar cane may further reduce these effects. Yet until recently, the government has designed its ethanol policy as a means to mitigate oil price fluctuations rather than for environmental purposes, and therefore cut support whenever oil prices were low. Also, despite some technological innovations, like the domestic development of new flex-fuel combustion engines, little has been undertaken to develop new industrial capabilities.

Finally, Pegels discusses the German Energiewende, the transition from coal and nuclear to renewable energy and enhanced energy efficiency, from the perspective of economic co-benefits. Her analysis shows that Germany has made considerable progress in the deployment of renewable energies for electricity generation, whereas other areas, such as energy efficiency, are lagging behind expectations. Regarding manufacturing industries, Germany's wind energy industry has emerged as a new global leader. Other sectors have been less successful. The solar panel industry boomed for some years but then experienced many bankruptcies due to competition from low-cost imports. Employment in Germany's environmental goods and services sector reached an estimated 260,000 jobs as of 2013. Also, rising electricity prices may have reduced the competitiveness of energy-intensive industries, a condition that is difficult to quantify.

Overall, the report provides a comprehensive overview of the rationale for environmental transformation, of the synergies and potential trade-offs among social, economic and environmental objectives and of different policy approaches and experiences of practical implementation in a wide range of country contexts. We hope it helps analysts and practitioners to accelerate the green transformation in a way that harmonises societal objectives in the spirit of the 2030 Agenda for Sustainable Development.

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PART 1: CONCEPTUAL FOUNDATIONS

CHAPTER 1

GREEN INDUSTRIAL POLICY: ACCELERATING STRUCTURAL CHANGE TOWARDS WEALTHY GREEN ECONOMIES

Tilman Altenburg, Dani Rodrik

1. INTRODUCTION

There are two major reasons for governments and societies to accelerate structural change in their economies and proactively shape the direction of the change. First, there is the challenge of creating wealth. Structural change, that is, the reallocation of capital and labour from low- to high-productivity activities, is a key driver of productivity growth and higher incomes. This is particularly important for developing countries where incomes are low and poverty is pervasive. According to the latest available estimates, 767 million people lived on less than US$ 1.90 a day, and 1.9 billion people in the developing world still had less than US$ 3.10 a day in 2013–a clear indication that the current structural composition of national economies does not provide a sufficient number of productive jobs (World Bank 2016). Second, economic development has so far been achieved at the cost of severe overexploitation of natural resources. Humanity is approaching various ecological tipping points beyond which abrupt and irreversible environmental change at large geographical scales is likely to happen (Rockström et al. 2009). Radically new techno-institutional systems are needed to decouple economic development and human well-being from resource depletion and waste production. While many of the required technologies are already available, the incentives guiding resource allocation need to change profoundly to disrupt current unsustainable technological pathways and change some economic subsystems entirely, such as those for energy provision and transport (IPCC 2014).

This chapter explores the policy options for managing structural change that accounts for both the productivity and the environmental challenges in a harmonised way.[2] This is a challenge for all countries. Yet we put developing economies at the centre of our analysis because this is where the need to accelerate wealth creation is greatest, and many stakeholders perceive this as incompatible with environmental conservation. Governments typically put economic growth above environmental objectives, arguing that part of the income generated can be used to clean up at a later stage. Also, the policy discourse has often been biased towards specific objectives: Industrialists have mainly sought solutions modeled after the successful cases of early industrialising countries with whom developing countries should catch up, ignoring the limits of our planet's carrying capacity. Environmentalists have tended to put conservation first and downplay the challenge of creating wealth for billions of people who aspire for a better material life. In this chapter we make an effort to bring these perspectives together and suggest ways of balancing the inherent trade-offs.

Industrial policy is our analytical angle. Industrial policy refers to government actions to alter the structure of an economy, encouraging resources to move into particular sectors that are perceived as desirable for future development. Traditionally, industrial policy has focused on productivity enhancement as the key mechanism that would ensure rising returns to capital and labour and thus enable economic growth and prosperity. Increasingly, however, the goals of industrial policy have been broadened. In practice, industrial policy agencies undertake measures to influence structural change such that regional disparities are reduced, labour-intensive industries or small enterprises are encouraged and/or the economy becomes environmentally more sustainable (Altenburg and Lütkenhorst 2015). The main objective of this chapter is to show how industrial policies can be designed to deal with the dual challenge of shifting economic structures in a way that prosperity is increased while at the same time replacing environmentally unsustainable activities with sustainable ones. The rationale for industrial policy rests on the idea that market prices are not always the best guide to allocating investments. We shall argue in the chapter that this idea applies with much greater force where climate change and green technologies are concerned.

A quick word about the term 'industrial policy': We use this term because it has a well-recognised meaning and a long history. But the range of policies we shall cover goes much beyond industry itself. In view of this, some terms that have recently come into use, such as structural transformation policies or productive development policies, would perhaps have been more appropriate. We stick with the traditional term; though we caution the reader that the kind of issues we cover here concern entire economies and not just manufacturing industries.

2 While this chapter puts the dual challenge of creating wealth and greening economies at the centre of its analysis, industrial policy should in fact be assessed against a wider range of societal objectives, as laid down in the 2030 Agenda for Sustainable Development (UN 2015). Increasing employment opportunities for youth, reducing regional disparities or supporting women's entrepreneurship are all legitimate goals. Ultimately, industrial policy has a normative content that depends on what societies define as desirable future courses for social and economic development (Altenburg and Lütkenhorst 2015).

We proceed in three steps. Section 2 analyses the dual challenge in greater detail. It first summarizes what we know about the link between structural change and wealth creation; it then addresses the need to decouple human development from non-renewable resource consumption and pollution, and it shows how this translates into a structural transformation of economies, including those of developing countries. The section ends with a discussion of synergies and trade-offs between the two objectives. Sections 3 and 4 then deal with the design of industrial policy. In section 3 we extract the main lessons from various decades of controversial debate on industrial policy and bring out three key principles of smart policymaking that maximise the governments' ability to overcome market failures while keeping the inherent risks of misallocation and political capture to the minimum. Section 4 takes this debate one step further, exploring the extra challenges of a green transformation and in what ways green industrial policy must go beyond the common practice of industrial policy in a business-as-usual setting. Section 5 concludes.

2. THE DUAL CHALLENGE: CREATING WEALTH FOR A GROWING POPULATION WHILE STAYING WITHIN PLANETARY BOUNDARIES

2.1. CREATING WEALTH: THE NEED FOR STRUCTURAL CHANGE

Productivity growth is a precondition for improving living standards and maintaining competitiveness in the globalized economy. Low total-factor productivity is one of the main reasons for persistent poverty in developing countries. Low income and lower-middle income countries in particular need to boost productivity growth to reduce poverty. This implies the pursuit of more productive ways of doing business within each existing sector as well as to accelerate the structural transformation across sectors, reallocating resources from low productivity activities in agriculture, small trade and simple services to new activities that are knowledge-intensive and exploit the advantages of inter-firm specialisation.

Countries get richer as they diversify their pools of knowledge and create institutions that facilitate continuous recombination of this knowledge for the improvement of existing or creation of new and better goods and services. Empirically, the link between increasing diversification of production and employment and rising incomes is very clear, at least at early stages of development (Imbs and Wacziarg 2003). Except for some natural resource exporting countries, the countries that achieve the highest incomes are the ones that are able to combine diversified knowledge pools in ways that are difficult to emulate by others (Hausmann et al 2014).[3]

Manufacturing plays an important role in the process of diversification. The manufacturing sector is particularly well-suited for serial production allowing for enormous economies of scale. On average, it supplies highly productive and well-paid jobs; it is where most private sector research and development and commercial innovation take place and where most royalties are generated. It generates demand for jobs in upstream and downstream activities from mining to distribution as well as production-oriented engineering, information technology and financial services. Due to this innovativeness, manufacturing creates particularly large knowledge spillovers which enhance productivity in non-manufacturing activities (Cohen and Zysman 1987; Helper et al. 2012). Also, productivity convergence—that is, sectors that are further away from the technological frontier increase productivity faster than the more advanced ones—appears to be especially rapid in manufacturing (Rodrik 2013). Last but not least, most manufacturing goods are easily tradable and can therefore be exported to world markets almost without demand restrictions;[4] this allows countries to reap economies of scale even when their internal market is constrained by low purchasing power and small population size. Historically, there is a clear correlation between phases of economic growth and expansion of the manufacturing sector (Rodrik 2006). Looking at the post-WWII performance of developing countries, the most

3 This dynamic is captured in the Economic Complexity Index developed by Hausmann and others. In their Atlas of Economic Complexity, the authors show how strong the correlation is when natural resource exporters are excluded (Hausmann et al. 2014).

4 By comparison, "an expansion of non-tradables is self-limiting, as the domestic terms of trade eventually turns against non-tradables, choking off further investment and growth" (Rodrik 2006).

impressive growth stories were based on export-led growth in manufactures, particularly in East Asia (Stiglitz and Yusuf 2001; Commission on Growth and Development 2008).

However, the share of manufacturing value added in GDP tends to have a historical maximum, beyond which it starts to decline. This transition towards post-industrial economies happens due to three factors. First, technological progress in manufacturing reduces demand for workers and shifts employment to services, where the potential for automation is not as big. Second, as incomes rise, demand shifts away from food and manufactures to increasingly differentiated services. Third, manufacturing industries become more and more knowledge-intensive and therefore create demand for specialised production-oriented services in areas such as engineering, information technology and finance. It should be noted that the boundaries between manufacturing and services are increasingly blurred and the interdependency of manufacturing and services increases. This is reflected in an increasing share of value added from services embodied in manufacturing products (OECD 2015).

The problem of today's developing economies is that, with the exception of some East Asian countries, manufacturing value added and employment tend to stagnate at very low levels. Most developing countries are moving from agriculture or mining as their main economic drivers to services without going through a proper process of industrial development, a process known as premature deindustrialisation (Rodrik 2016). In Latin America, manufacturing industry`s contribution to GDP and employment has peaked early at a much lower level than one would have expected from the patterns of today's industrialised countries and is now shrinking. In Africa, manufacturing industries are stagnating at a low level (Diao et al. 2016). The same study finds that labour productivity is stagnant or even declining in the modern sectors. Given the importance of manufacturing and modern services as drivers of diversification and productivity growth these trends cast doubts on Latin America's and Africa's prospects for future economic growth and welfare.

Two factors are particularly important to understand these trends: labour-saving technological progress and globalization (Rodrik 2014). New technologies are reducing demand significantly for routine labour activities in manufacturing and services (Brynjolfsson and McAfee 2014). For the US, Frey and Osborne (2013) calculate that about 47 per cent of jobs are susceptible to computerization in the next few decades. Applying the same methodology to developing countries, the World Development Report 2016 finds even higher automation potentials–two thirds of today's jobs in developing countries could be lost to automation, for instance–but assumes that automation will proceed more slowly due to time lags in technology adoption (World Bank 2016:219).

In the past, reallocating workers from low productivity agriculture to export-oriented light manufacturing activities was a powerful driver of industrialisation and productivity growth. East Asian economies especially benefited from this shift, from Korea and Taiwan in the 1970s to more recent industrialisation experiences in China, Vietnam and Cambodia. Progress in labour-saving technologies, however, is now likely to radically reduce the opportunities for boosting productivity through the attraction of investment in labour-intensive export industries. At the same time, globalization creates new opportunities for industrial development as it facilitates access to hitherto inaccessible technologies and markets. However, it can also accelerate premature deindustrialisation as it puts newly emerging small industries in direct competition with highly competitive global corporations that have accumulated knowledge and network externalities over decades and, on top of that, exploit the economies of scale associated with globalized markets. Even in the latecomer countries' own domestic markets, imports often stifle local industry development. While a number of highly competitive firms and regional clusters in developing countries have been able to reap the opportunities of global markets, such successes have been the exception rather than the rule. This explains why since the 1950s, "very few [countries] have become high-income economies. Most developing countries have become caught in what has been called a middle-income trap, characterized by a sharp deceleration in growth and in the pace of productivity increases" (Agénor et al. 2012).

The few successful upgraders include oil exporters and Eastern European countries benefiting from EU accession, as well as East Asian countries. The latter in particular placed emphasis on technological learning and capacity building, especially in manufacturing. They had institutions in place to manage structural change, providing coordination for the emergence of new economic activities, nurturing entrepreneurship and investing in education and skills development to ensure that human capital adapts to changes in the productive structure (Amsden 1989; Wade 1990). The lesson from their success is clear: the creation of wealthy economies is strongly correlated with the ability to manage structural change in a way that enhances productivity in a socially inclusive way.

2.2. TAKING ECOLOGICAL BOUNDARIES INTO ACCOUNT: A GAME-CHANGER FOR STRUCTURAL CHANGE

The global economy is on an unsustainable path. Since the industrial revolution, the world economy has grown at the expense of the environment. Natural resources have been exploited without allowing stocks to regenerate, pollutants have accumulated in the biosphere, ecosystems have been degraded severely and biodiversity has been lost at an alarming rate. Already in the early 2000s, the Millennium Ecosystems Assessment, a UN-led global assessment of the Earth's ecosystems, concluded that about 60 per cent of the ecosystem services examined had been degraded or were used in ways that cannot be sustained (MEA 2005). Similarly, UNEP (2011) summarises a series of reports showing severe overexploitation of fish stocks, increasing water scarcity, decreasing soil quality and unsustainable rates of deforestation.

Through product and process innovations, resource efficiency is increasing worldwide. Put differently, fewer natural resources are needed to produce the same unit of output; but this increase in efficiency has been quite modest, with the effect that GDP growth globally has more than outweighed the efficiency gains (Jackson 2016; Wiedmann et al. 2015). This led to a situation where "global material extraction more than doubled in the past 30 years, from around 36 billion tonnes in 1980 to almost 85 billion tonnes in 2013, an overall growth of 132 per cent" (Vienna University of Economics and Business 2016). Environmental contamination also increased. In the case of anthropogenic greenhouse gases, emissions rose from 33 to 49 Gt CO_2e per year from 1980 to 2010 (IPCC 2014). Due to continued growth of the global population and increased per capita consumption, particularly since the turn of the century, "anthropogenic pressures on the Earth System have reached a scale where abrupt global environmental change can no longer be excluded" (Rockström et al. 2009). Research on environmental systems highlights the existence of tipping points at which environmental change accelerates due to self-reinforcing mechanisms and systems are unable to restore their previous equilibrium (Lenton et al. 2008).

Global warming is the most pronounced threat to human development and the environment. The International Panel on Climate Change predicts that if we continue to manage our economies in the same way, global mean surface temperature will increase by 3.7°C to 4.8°C by 2100 compared to the average for 1850 to 1900 (IPCC 2014). Melting of polar ice and thawing of permafrost soils are two dangerous accelerators of global environmental change. But there are other big threats to the Earth System calling for urgent action including loss of biodiversity, ozone depletion, ocean acidification, water shortage, soil degradation, accumulation of nitrogen in aquatic ecosystems and the accumulation of chemical waste and plastics (Rockström et al. 2009; WBGU 2014).

These fundamental threats to humanity need to be taken into account when thinking about further growth and structural change of economies. The way economic transactions are currently organized largely ignores the social cost of resource depletion and pollution. Natural capital embodied in fertile soils, fresh water, clean air and productive ecosystems is being wasted. This waste undermines the basis for future economic development and jeopardizes the progress made on social welfare (Fay et al. 2015). Therefore, we need to recognise environmental sustainability as fundamental to the production process.

In essence, human well-being and economic progress need to be decoupled from non-renewable resource consumption and emissions (UNEP 2011). To make economic development sustainable, resource efficiency needs to increase at least at the same rate as economic output. The largest challenge is how to achieve the steep decline in GHG emissions needed to keep global temperature rise well below 2°C. To achieve this, global carbon intensity would have to be reduced by 6.3 per cent every year to 2100, much faster than the modest annual decline of 1.3 per cent achieved between 2000 and 2014 (PwC 2015).

So far, none of the major economies has achieved this. However, 'absolute decoupling' is not impossible. Enormous resource efficiency jumps are technologically feasible: with the shift to renewable energy, the use of smart information and communication technology systems, the use of energy-saving technologies and, last but not least, changes in consumer behaviour. To accelerate the required technological and business model innovations, however, economic incentives need to be set very differently. Above all, environmental costs need to be much better reflected in prices, regulations must be tightened and subsidies for fossil fuels and other unsustainable goods and practices need to be phased out.

Doing so will invariably have deep and system-wide implications, comparable to those observed during the first industrial revolution or the rise of information technology (Pérez 2002). It will change the way we farm our land and manufacture goods, where we source our energy, how we transport things and how we build our infrastructure and design our cities. Among the various environmental challenges, mitigating climate change will have arguably the deepest implications for structural change because it affects the energy and transport sectors that so far have fuelled economic development, literally. According to the Intergovernmental Panel on Climate Change, global annual CO_2 emissions will need to be reduced 42 to 57 per cent by 2050, relative to 2010, and 73 to 107 per cent by 2100 (IPCC 2014). To achieve such levels of decarbonisation, major systemic changes are indispensable: Electricity generation needs to shift fully from fossil to renewable sources; as power generation is decarbonised, transport, heating and other energy using sectors need to be electrified, including road traffic; and resource efficiency needs to be increased radically across all industries, including the shift to circular economies where waste is reduced, reused or recycled (Fay et al. 2015).

Some of these changes are already in full swing, others yet to come. Global energy systems–and all the related manufacturing and service activities related to power generation, transmission and storage–are already undergoing a fast and radical change. Renewable energy technologies have been adopted widely around the world. Electricity from hydro, geothermal and certain biomasses can now compete with fossil fuel-based electricity, as do wind and solar power in good locations, and further cost reductions are expected. While 15 years ago renewable energy power installations played a negligible role in global electricity generation, “the world now adds more renewable power capacity annually than it adds in net new capacity from all fossil fuels combined” (REN21 2016; REN21 2017).

Firms continuing to invest in unsustainable technologies run the risk of having to write off major investments. According to McGlade and Ekins (2015), climate research suggests that “to have at least a 50 per cent chance of keeping warming below 2°C throughout the twenty-first century, the cumulative carbon emissions between 2011 and 2050 need to be limited to around 1,100 gigatonnes of carbon dioxide.” As a consequence, about one third of oil reserves, one half of gas reserves and at least 80 per cent of known coal reserves cannot be burnt and need to be kept in the ground if catastrophic climate change is to be avoided (McGlade and Ekins 2015). Fossil fuel reserves as well as assets that depend on transforming and trading fossil fuel, such as refineries, power plants and petrol distribution networks, may therefore be overvalued. Rapid technological progress in low-carbon technologies and/or more ambitious decarbonisation policies may force the holders of carbon assets to adjust their values, which in turn may cause a carbon bubble shock with deep repercussions for banks, pension funds and insurance companies (Weyzig et al. 2014). The Economist Intelligence Unit estimates that within the global stock of manageable assets the value at risk due to climate change ranges from US$ 4.2 trillion to US$ 43 trillion between now and the end of the century (EIU 2015). The Financial Stability Board recognises such asset stranding related to climate change to be a relevant risk to the global financial system and therefore put a reporting system in place, the Task Force on Climate-related Financial Disclosure (TCFD 2017). In fact, some institutional investors have started to withdraw from carbon assets (Schwartz 2015). Hence there are market mechanisms at work that accelerate the structural change towards a low-carbon economy.

While mining and power supply industries are most affected, structural change in other industries is following. Regulators in all main automotive markets including the European Union, USA, Japan and China, have defined roadmaps for reducing average CO_2 emission levels of new cars. Within a few years, these levels can no longer be achieved by efficiency gains in fuel-driven cars alone, forcing manufacturers to incorporate electric and hybrid cars into their product range and to rapidly increase their share in overall sales. The private sector is in fact responding. Electric vehicle deployment has recently taken off with exponential growth rates, albeit from a low basis. In 2016, the global stock of electric cars exceeded two million, up from a few hundred ten years earlier (OECD and IEA 2017). With rapidly falling battery prices and increasing battery performance, electric cars will soon be fully competitive with fuel-driven cars (Altenburg et al. 2017, this volume). Early movers such as Tesla and Toyota are taking market shares from established carmakers that have been slower to adapt. Similar changes can be observed in other product categories: reflected in growing markets for organic food, biodegradable packaging and renewable building materials, for example.

Not only products will change, but also production processes and business models. Circular economy models are being developed to minimise material and energy flows through industrial systems and make sure residuals of one production process are used as input for another (Ellen MacArthur Foundation 2012). In energy systems, new technologies enable the development of decentralized mini grids where customers can flexibly respond to price signals, supplying power or reducing demand when the price on the grid is high and consuming power when it is low (Nathaney et al. 2016). Worldwide, new business models are flourishing, models based on sharing rather than owning assets, in most cases facilitated via online marketplaces. These include sharing of cars, accommodation or taxi services. Last but not least, the certification and accreditation industry is receiving a boost, as economic actors are increasingly obliged to prove that their production processes comply with various environmental requirements.

In sum, the recognition of ecological system boundaries has already become a game-changer for economic development. Incentive systems are changing–still too slow from an environmental perspective–and a lot of experimentation is happening in terms of new products and processes.

2.3. CHANGE WILL AFFECT DEVELOPING COUNTRIES

How relevant are these changes for developing countries, taking into account that "many are unable to keep up with the investments to satisfy the basic needs of their citizens, let alone the efficient cities, roads, housing, schools, and health systems they aspire to create" (Fay et al. 2015:2)? In fact, many people in developing countries, including government officials, regard environmental protection a luxury their countries should deal with at later stages of development, once the more pressing problems of human development have been solved.

Still, even when governments put their own national social and economic objectives first, there are strong arguments for not delaying the transition to a green economy (Padilla 2017 and Ambec 2017, this volume). First, environmental degradation undermines the ecological foundations for economic growth and human well-being, most obviously in countries that depend on economic activities in agriculture, forestry or fisheries. Second, pollution and waste typically reflect inefficiencies in production, and resource-saving techniques tend to amortize very quickly even without consideration of positive externalities. Third, sticking to traditional products and processes as the worlds' dominant economic actors shift to greener goods and production techniques will drive a wedge between local and global practices. This makes it more difficult to compete in the future, considering that trade and investment treaties increasingly regulate environmental issues and that lead firms in global value chains impose progressively higher environmental standards. Fourth, countries should avoid getting locked into unsustainable infrastructure and business practices because the costs of switching in the future will likely be disproportionally high. Therefore, today's investments in high-carbon energy infrastructure may turn into financial burdens soon, as renewable energy becomes cheaper and commitments to decarbonise become binding and costly. Developing countries are in an advantageous position in the sense that most of their energy and urban infrastructure is yet to be built, so they can avoid costly misdirected investments in unsustainable infrastructure. Fifth, many new green technologies come with co-benefits. For example, investing in clean air greatly improves health conditions and reduces health-related expenditures; and communities can be electrified at lower cost when new technologies make it easier to use local sources of renewable energy at small scales. Sixth, green industrial policies drive innovation. While new-to-the-world types of innovation will mostly likely be developed in a relatively small number of countries with strong national innovation systems, certain innovations may also be developed in poorer countries and drive local productivity growth and job creation. Table 1.1 provides an illustrative overview of new green product and service opportunities, differentiating between countries by level of income.

Table 1.1: New green product and service opportunities for countries at different income levels

	Higher middle and high income countries	Low and lower-middle income countries
New products	Renewable energy technologies including high-tech components of solar photovoltaics, concentrated solar power, wind turbines and geothermal technologies; energy storage technologies including fuel cells and lithium-ion batteries; electric vehicles; new lightweight materials; bioplastics; carbon capture and storage technologies; high performance building façades.	Low- and medium tech, low cost products such as solar water heaters, solar water pumps, solar driers; drip irrigation systems; rainwater harvesting technologies; LPG, LNG or ethanol cook stoves; LNG-based three-wheeler taxis. Inputs for global green production for which factor endowments exist: such as lithium, rare earths, cellulosic ethanol.
New services	Design and operation of smart grids, closed-cycle eco-industrial parks, intelligent transport systems, advanced energy management systems, electronic road pricing, tracking and tracing systems for environmental performance along value chains.	Simple low-cost services such as for operation and maintenance of decentralized and mini electric grid solutions; labour-intensive waste recycling; low-carbon livestock management; management of rapid transit systems. Labour-intensive tasks in emerging green global value chains, such as assembly of solar panels or lithium-ion cells.

Source: Adapted from ClimateTechWiki (n.d.).

In fact, awareness of the need for green industrial policy is clearly increasing among developing country stakeholders. Governments of countries at very different income levels have enacted green economy strategies, ranging from Ethiopia, Rwanda, Cambodia and Vietnam to Mexico and China. Growing recognition is also reflected by the 197 countries party to the 2015 Paris Agreement under the United Nations Framework Convention on Climate Change, thereby committing to limit the increase in the global average temperature to well below 2°C above pre-industrial levels, to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels and to formulate and communicate long-term low greenhouse gas emission development strategies. So far, the existing commitments, known as Nationally Determined Contributions, are not sufficiently ambitious to stay below the envisaged threshold levels (Climate Action Tracker 2015), and we may expect a gap between political declaration and actual implementation; but the trend towards greener technologies and incentive systems is unlikely to be reversed. Especially in the field of energy generation, renewable energy technologies are becoming much more cost-efficient in many more locations. Developing and emerging economies now account for about half of global renewable energy investments and the market for renewables-based mini-grids is booming (REN21 2017). With regard to air pollution, many developing countries and municipalities have taken drastic measures to regulate transport. These include measures to reduce allowable fleet emissions, to restrict access of high polluting vehicles in inner cities or to oblige taxi fleets to run on ethanol or compressed natural gas.

2.4. THE DUAL CHALLENGE

Governments around the world are thus confronted with a dual challenge: to accelerate structural change towards higher productivity in a way that is socially inclusive and to align economic development with the carrying capacity of our planet. Recognizing the need to harmonise both objectives and to make industrial policy environmentally sound is essential. In this regard, the unanimous global agreement on the 2030 Agenda for Sustainable Development has been a major achievement (UN 2015).

However, not a single country has been able, so far, to enhance the welfare of its citizens without increasingly depleting its resource base. In this regard, governments in search of a welfare-enhancing sustainable economy are entering uncharted territory. There are obvious trade-offs between the welfare and environmental sustainability objectives, at least in the short and medium term. Ostensibly, internalizing environmental costs that have been externalized in the past increases the apparent cost of production and reduces cost-competitiveness if competitors do not have to bear these costs. Moreover, green investments have opportunity costs: governments need to find a good balance between the necessary investments in environmental improvements and other outlays, such as those for health, education and infrastructure. But there are multiple synergies as well. The search for green technologies will create many opportunities for economic development, health benefits, improved efficiencies and better living conditions. Governments must understand these synergies and trade-offs to be able to design green industrial policies while Maximising gains and minimizing costs. This will be challenging, given that optimal solutions depend on situation-specific factors–from resource endowments and techno-institutional capabilities to the distribution of power between the polluting incumbents and green newcomers.

3. THE ROLE OF INDUSTRIAL POLICY

Unfettered market-based allocation of resources is unlikely to foster structural change in a socially optimal manner, one that allows for high productivity, broad-based societal inclusion, generalized wealth and increasing environmental sustainability. In many instances, markets do not send out the right price signals. This is the case when an initial investment that would have triggered many knowledge spillovers is not carried out because the investment in itself does not immediately pay off in a way the individual financier could appropriate the profits stemming from all the resulting secondary technological developments and market opportunities. In other words, the social or public returns are larger than the individual or private returns, which is a very common phenomenon given the cumulative character of technological development. Market-based resource allocation also has its limitations in the presence of coordination failures. These occur when the viability of a new business depends on simultaneous investments in related fields, with the effect that no firm risks an investment unless someone guarantees the necessary complementary investments. Similarly, markets do not facilitate the socially optimal level of entrepreneurial 'discovery' of cost: When an investor undertakes a new activity, he or she discovers the underlying costs, as well as the benefits (Hausmann and Rodrik 2003). However, this knowledge, especially the likelihood of high returns, quickly becomes public and other investors will copy the business model. This is good for the overall economy, but bad for the pioneering investor who bore the full risk of failure but sees his innovation profits dissipate. Put differently, the social value of discovering the cost of a new activity exceeds the private gains. This is another important market failure. Similar market failures occur, for example, when markets do not reflect the full environmental costs of an investment or when market actors lack relevant information.

This is where industrial policy enters the scene. It has important roles in encouraging industries with potential knowledge spillovers, coordinating interdependent investments, subsidizing early entrepreneurial search processes, promoting cleaner industries and facilitating market transparency and information flows. Generally speaking, industrial policy aims to reinforce or counteract the allocative effects of markets with the objective of restructuring economies towards a better societal outcome (Rodrik 2004). It should be noted that industrial policy is about promoting desirable structural change in general and not limited to industry or even to manufacturing.

Here, an important qualification is in order to avoid a common misinterpretation of industrial policy. Proponents of modern industrial policy do not think policymakers are better than entrepreneurs in anticipating market opportunities. They know the market mechanism is a smart institutional arrangement. In many regards, markets reflect what people want and how much they are willing to pay for alternative options. Also, markets encourage the creativity of individuals who take personal risks in the pursuit of profits. Ideally, competition among firms with different business concepts will reward efficient entrepreneurs and force less efficient ones out of the market. It is this process of entry, innovation and exit in a competitive environment that drives productivity growth and determines where firms, regions, or countries have relative advantages. The role of industrial policy is not to replace this creative process with top-down bureaucratic planning, but to embed it within broader social welfare processes to improve the outcomes for society at large.

Beyond externalities and coordination failures, societies tend to have different preferences, many of which cannot be fully expressed in market prices–often because they imply ethical considerations or touch upon entrenched societal values. For example, people have different preferences when it comes to attaching economic values to cultural norms or to biodiversity. This affects how people strike their personal balance between economic opportunities and the related risks of, for instance, genetic engineering, global warming or nuclear energy. People also differ with regard to the degree of social inequality or employment insecurity they are willing to accept. Also, they have different views on where, how much and with which measures the state should interfere to regulate such issues. Against this background, industrial policy is about facilitating stakeholder dialogues on the direction of structural change, moderating different viewpoints, finding compromises and creating consensus on broadly defined development pathways. As well, it is about adapting regulatory frameworks and incentive schemes in such a way that creative entrepreneurial search processes are encouraged and channelled towards the achievement of agreed goals. This again implies strategic collaboration between the private sector and governments to jointly identify barriers that need public-private coordination for their removal.

In essence, industrial policy aims to complement the market mechanism. Given the pervasiveness of market imperfections and the legitimacy of investment criteria that go beyond microeconomic efficiency, the question is not whether to apply industrial policy or not, but how to do it (Rodrik 2004).[5]

Critics point to various ways in which industrial policy is frequently being abused by interest groups. Industry lobbyists demand specific subsidies and orchestrate resistance when subsidies shall be withdrawn. As there are usually substantial information asymmetries between the lobbyists and the public sector it is often easy to develop a storyline justifying subsidies. Similarly, politicians may claim and allocate funds to satisfy electorates and protect firms in their jurisdictions rather than to maximise public welfare on the basis of scientific evidence. Keeping such political capture to a minimum is indeed a major challenge.

To cope with this challenge, three basic principles of effective industrial policymaking should be applied when designing and implementing industrial policy (Rodrik 2014; Altenburg et al. 2008):

1. **Embeddedness**. Policymakers need to maintain close relationships with the private sector and other stakeholders to get a deep understanding of how specific economic sectors function, what the business rationale of relevant private actors is and where bottlenecks exist that hold back improvements. To what extent government intervention is necessary and what instruments are best suited to overcome market failures depends on the gap between what self-organized private actors would achieve and the optimal outcomes in the public interest. This is likely to be very context-specific and to change over time. Industrial policy should thus be conceived as a collaborative process of discovery in which public and private actors closely interact and continuously negotiate and adapt their contributions to the development of the respective industry.
2. **Discipline**. Such embeddedness obviously entails risks of collusion and capture by private interests. To minimise these risks, governments need to maintain full autonomy in decision-making and be able to use disciplining devices against abuse (Evans 1995). Governments need to draw a clear line between collaboration in the public interest and favouritism. This presupposes clearly defined objectives that are broken down into measurable performance indicators. Furthermore, it requires monitoring and evaluation routines to continuously check the performance of firms and support programmes against existing benchmarks. Governments need to have the independence to adjust or even withdraw incentive packages without falling prey to lobbyists. Unbundling the roles of policy formulation, funding, implementation and evaluation can be helpful to insulate such performance-based systems against political interference. Putting implementation out to tender, encouraging competition among service providers and monitoring their performance through independent agencies further enhances effectiveness. Clear and transparent rules as well as conditionality and sunset clauses are also helpful to keep rent-seeking behaviour in check.
3. **Accountability**. Policymakers and implementing agencies should be held accountable for their industrial policies. This can be achieved using various reporting requirements and obligations to disclosure as well as more general democratic checks and balances by central auditing authorities, political parties, independent courts and a free press. Accountability serves not only to prevent corruption, favouritism and other forms of collusive behaviour but also helps to legitimize appropriate industrial policies.

5 Countries that managed to close the technological and income gap vis-à-vis more advanced economies invariably employed a range of carrots and sticks to protect and nurture their national industries. Empirical evidence shows this for the early catching-up experiences of Germany, the United States and Japan as well as for the more recent post-World War II examples, from the early "Asian Tigers" of Korea and Taiwan to the current emergence of China. None of the countries that strictly followed the Washington Consensus, in contrast, has achieved comparable success in terms of technological upgrading, economic growth, and poverty reduction (Rodrik 2005; Chang 2009).

4. GREEN INDUSTRIAL POLICY: HOW IT IS DIFFERENT

Industrial policy is about anticipating relevant long-term trends of technology and market development and providing incentives to adapt the structure of a national economy in such a way that it can take advantage of the change. As climate change mitigation and other ecological challenges increasingly influence the future direction of economic development, environmental considerations need to become a key part of industrial policymaking. This is what green industrial policy is about (World Bank 2012; Hallegatte et al. 2013; Lütkenhorst et al. 2014; Pegels 2014).

The boundaries between green industrial policy and environmental policy are not clear-cut. Environmental policies aim at protecting and sustainably using our natural environment. Intentionally or not, some of these policies drive structural change. For example, carbon prices shift investments from fossil fuels to renewable energy; ambitious automobile emissions standards accelerate the substitution of traditional fuel with electric vehicles that in turn requires different types of supplier industries; environmental fiscal reforms that tax environmental consumption instead of labour may reduce the international competitiveness of resource-intensive industries while making labour-intensive activities more competitive. Other environmental policies mainly induce process innovations and thereby have only little effect on structural change, such as new pollution control technology upgrades in existing industries. In this volume, environmental and energy policies that deliberately push structural change into the desired direction are considered part of green industrial policy. In addition, it encompasses policies that enhance the national benefits of the green transformation in terms of higher incomes and better employment opportunities. Hence, we define green industrial policy as including any government measure aimed to accelerate the structural transformation towards a low-carbon, resource-efficient economy in ways that also enable productivity enhancements in the economy.

How is green industrial policy different from industrial policies that do not systematically integrate the perspective of environmental constraints? In many ways, steering investment towards a green economy is not that different from steering them towards conventional industrial policy objectives, such as higher value added and enhanced productivity. As Schwarzer (2013:vi) puts it, "…green industries are essentially infant industries, with all the characteristics of conventional infant industries and subject to the same opportunities and challenges of promoting them." Various information and coordination failures call for facilitation. Policymakers as well as entrepreneurs take decisions without knowing what the future will look like; therefore, policies carry risks of misallocation and political capture, which need to be kept to a minimum. Also the available instruments are very similar, including information and coordination platforms, regulations, standards and labels, differential taxes and credit subsidies. And the three basic principles of effective policymaking apply. Finally, as in conventional industrial policy, shifting to new green industries requires public support and therefore needs to find ways for dealing with the 'losers' and smoothing the adaptation of firms and workforce (Fay et al. 2015). This is why the researchers and practitioners concerned with green transformation can learn many lessons from the conceptual discussions about industrial policy and its successes and failures of implementation.

Yet, green industrial policy is also different. It goes beyond the traditional notion of industrial policies in at least six important ways (Altenburg and Pegels 2012; Lütkenhorst et al. 2014):

1. the focus on environmental externalities as an additional and particularly damaging market failure
2. a clear predictable distinction between 'good' and 'bad' technologies, based on their environmental impacts, and therefore systematic steering of investment behaviour in a socially agreed direction

3. the urgency to achieve structural change within a short period of time, to preclude the risk of catastrophic environmental tipping points
4. enhanced uncertainty due to long time horizons of some transformations as well as dependence on policy changes
5. additional policy interfaces and therefore the need for particularly encompassing policy coordination
6. a motivation to manage global commons, such as the atmosphere and oceans, for long term sustainability, which may not always be aligned with immediate national interests.

In what follows, we will address each of these defining features one by one.

4.1. THE IMPORTANCE OF ENVIRONMENTAL EXTERNALITIES

The most obvious specificity of green industrial policy is that it aims to correct the failure of markets to reflect the social costs of environmentally harmful production. For companies investing in green technologies, the private return lies significantly below the social return, resulting in underinvestment. Quoted in The Guardian Newspaper, regarding his report for the UK government, Stern tells us "Climate change is a result of the greatest market failure the world has seen" (Benjamin 2007; Stern 2007). Hence the theoretical case for applying industrial policies to accelerate and upscale investments in green technologies is even stronger than it would be for other technologies.

To close the gap between private and social returns the first-best solution would be to price the use of environmental goods, such as water or clean air. This has a big advantage: market actors can use their ingenuity to find the most cost-effective way to consume less of these goods. There are basically two ways that governments can attach prices to environmental goods: cap-and-trade systems and environmental taxes on resource consumption or emissions. In cap-and-trade systems, governments define an upper limit for the use of a resource or emissions and then distribute or auction use rights among economic actors, which can then be traded. This encourages all participants to explore and implement the most cost-effective solutions[6]. Defining the cap and allocating use rights, however, is not easy for political reasons. Polluter lobbies typically claim that ambitious caps would threaten their international competitiveness in order to keep the cap high and the price of use rights low; and they ask for assignment of free use rights. As governments do not want to harm their national industries, cap-and-trade systems so far have often failed to set ambitious caps (Helm 2010; IPCC 2014). Environmental taxes, in contrast, do not guarantee an upper limit to resource use or pollution because industry's readiness to pay taxes defines how much they will reduce that resource use or pollution. But taxes have several advantages. As they are directly set by a government authority, the additional cost for firms is more predictable. Also, taxes create a double dividend as they not only reduce environmental impacts but also raise revenues for the government. These can be used to reduce other taxes or increase government spending, both of which help to build societal support for environmental tax reforms. Finally, taxes are easier to implement than cap-and-trade systems, making them particularly attractive for developing countries (Schlegelmilch et al. 2017, this volume).

As market instruments that encourage entrepreneurial search and cost-effective allocation, both cap-and-trade and environmental taxes are increasingly being applied internationally. For several reasons, however, pricing environmental goods is not sufficient (Fay et al. 2015). One limitation is that there may be other market failures hampering green transformations–for example those related to incomplete information, lack of coordination or inadequate appropriability of research and development investments. Another limitation consists in ethical concerns about pricing. Not everyone would agree with the basic idea that everything nature provides can be expressed in monetary values. These critics hold, for example, that the preferences of future generations cannot be fully reflected in market prices. In addition, first-best policy instruments may not be available for political or administrative reasons.

Hence policy mixes are usually required that combine market-based instruments, regulations, capacity building, subsidies and other components in various ways. The right combination depends on country conditions, such as what degree of policy complexity can be handled and how well the government is insulated from lobbying pressure. Also, governments need to anticipate the trade-offs between pricing

6 For the case of climate change mitigation, Cramton et al. (2017) convincingly argue why a global carbon price would be much more effective than the current practice of individual pledges with weak review mechanisms. Rather than depending on altruism it would create a reciprocal common commitment, whereby "each country would commit to placing charges on carbon emissions sufficient to match an agreed global price formula."

environmental goods and competitiveness. Polluting industries will intentionally face higher costs and may therefore lose any advantage over competitors from other jurisdictions where the same industries are not taxed. At the same time, pushing industries early on to develop clean technologies may result in early mover advantages if other jurisdictions impose similar conditions with a time lag (Porter and van der Linde 1995; Ambec 2017, this volume).

4.2. SYSTEMATICALLY STEERING INVESTMENT BEHAVIOUR

The overarching objective of bringing the economy back into a 'safe operating space for humanity' necessarily gives structural change a direction (Rockström et al. 2009). First and foremost, traditional industrial policy aims at enhancing productivity growth and incomes but, in most cases, leaves it to market forces to find the most lucrative technologies and business models. Green industrial policy, by comparison, is driven by scientific evidence of environmental threats. This implies a much clearer picture of which technologies and business models are good or bad. Underlying green industrial policy is the Pigouvian idea of steering investment behaviour systematically and permanently towards what governments conceive as environmentally sustainable (Spratt 2013:12).

This leads us to four peculiarities of green industrial policy when it comes to issues of technology choice and promotion: First, there needs to be agreement on which technologies are good for a sustainable future. This is far from trivial because alternative solutions may exist, all with some trade-offs that imply difficult value judgments. For example, from a decarbonisation perspective, biofuels are desirable substitutes for fossil fuels, but their commercial production may lead to monocultures, loss of biodiversity, higher food prices and increased pressure on unutilized vulnerable land. In a similar vein, nuclear energy and large-scale carbon capture and storage are advocated by some as necessary elements of decarbonisation strategies but rejected by others for their inherent risk of large-scale contamination. What is desirable thus depends on value judgments, and political deals are needed to define what merits support.

Second, there is a case for subsidizing deployment of clean technologies, even beyond the point where they break even with harmful technologies. Traditional industrial policy would foster technologies only at their infant stage and withdraw support as soon as they start competing in the market place. In contrast, the logic of green transformations implies that where environmentally sustainable solutions compete with harmful ones it is in the public interest to accelerate the substitution rather than waiting for markets to reward commercially superior alternatives. Never and Kemp (2017, this volume) discuss how standards can be used to accelerate the diffusion of green technologies.

Third, an important part of green industrial policy is to proactively phase out harmful technologies. In some cases, such as when substances that deplete the ozone layer or greenhouse gases are concerned, it is not enough to promote the development and deployment of sustainable alternatives. Green industrial policy defines road maps and sets incentives to phase unsustainable technologies out. Cosbey at al. (2017, this volume) show how this can be done in practice.

Fourth, while conventional industrial policy rarely tries to affect consumer behaviour, influencing purchase decisions is an important element of green industrial policy. Mandatory labelling programmes may help to make markets transparent and enable consumers to distinguish products with different environmental effects. Educational programmes can encourage people to reuse and recycle things. However, it should be noted that consumers do not respond perfectly to price signals. Even when new products exist that are better in many ways and cheaper, many consumers stick to the bad old alternatives because they do not understand the situation well, because their neighbours have not changed or simply out of force of habit. Green industrial policy can use a wide range of options to encourage green consumption and shift markets using advertisements, nudges and green default options, among other schemes. A rapidly growing literature shows how insights from behavioural science can be used to influence consumers in a pro-environmental way (Sunstein and Reisch 2013; Price 2014).

4.3. URGENCY TO ACT FAST AND UPSCALE EXPERIMENTATION

Some economic activities have strong impacts on specific ecosystems or even on the entire Earth System. These ecosystems have a certain capacity to react to disturbances and return to their previous equilibrium state; but thresholds exist beyond which such return is no longer possible and systems may collapse, in some cases with potentially catastrophic effects for life on Earth (Lenton et al. 2008). It is thus truly vital to avoid such tipping points.

So humankind is approaching, or even transgressing, various thresholds at the global level where irreversible and catastrophic change may happen (Rockström et al. 2009). To stay within a safe operating space, quantum leaps in resource efficiency are needed that in turn require radically different technologies and business models in various fields. Among the various thresholds, global warming is the one for which the most sophisticated models exist to assess: how much carbon can still be emitted to keep warming below tolerable limits, by when the world economy needs to become carbon-neutral, how much the transition would cost and how much the cost would increase if action got delayed. While such calculations necessarily have methodological limitations, they all concur in their assessment that the necessary technology switch needs to happen within the next one or two decades if global warming beyond 2°C is to be avoided. Also, it is widely agreed that delayed implementation of mitigation measures will make it much more difficult and costly, if not impossible, to reach given climate targets. Costs increase–due either to greater environmental damages if targets are not met or to the greater stringency of the necessary mitigation measures if the original target is maintained–and opportunities to act early on low-cost mitigation measures are missed (Executive Office of the President of the United States 2014).

This provides a very strong rationale for green industrial policy that is ambitious and leads to results quickly. More mission-oriented innovation programmes are probably needed to facilitate big coordinated investments and accelerate the development of critical key technologies, such as for energy storage (Foray et al. 2012). In addition, sunset clauses and compensation schemes will be needed to phase out harmful technologies, as well as guarantees and subsidies to accelerate the dissemination of clean substitutes. Many of these policies involve risks of misallocation. Governments cannot know beforehand whether a certain public investment in a new technology or business model will pay off in the future. However, this is not an argument against such investments. If there are good reasons to assume that experimentation creates knowledge spillovers to society that are large compared to the private return on investment, supporting such experimentation makes sense. While this holds for industrial policy in general, it is particularly relevant for policy areas where solutions are needed urgently and quickly, because any delay leads to an escalation of costs. In the presence of tipping points in the Earth System, industrial policy support for sustainable technologies can hardly be overestimated. Also, it should be noted that there are ways to limit the risks of misallocation and share them with private investors, through competitive bidding processes and other means.

4.4. DEALING WITH ENHANCED UNCERTAINTY

Many of the objectives of a green transformation cannot be achieved in the short term. Decision-makers need to define long-term targets—such as the European Commission's target to cut the EU's greenhouse gas emissions to 80 per cent below 1990 levels by 2050—and then define intermediate milestones and derive technology and policy road maps for achieving the target (European Commission 2011).

With longer time horizons, uncertainty increases. Three types of uncertainty compound here. First, there is uncertainty about technologies and markets. These are always difficult to predict, but predictions become even more uncertain when systemic change is envisaged that stretches out over various decades. Moreover, considering that so far not a single country has succeeded in systematically decoupling economic welfare and growth from resource consumption, there are no role models for a green economy. Governments of developing countries are no longer well advised to emulate technologies and institutions from rich economies but rather need to find their own pathways.

Second, there is policy uncertainty. Green industrial policy is strongly driven by politically defined objectives, rather than by new technologies and market opportunities, which makes it essential to have predictable and stable long-term policy frameworks in place. Political factors–such as the level of ambition of policies to phase out coal or fuel-driven automobiles, the political will to implement carbon taxes or the willingness and ability to sustain preferential tariffs for renewable energy– strongly affect the profitability of investments (Karp and Stevenson 2012). At the same time, these political factors are often contested and they change when new administrations take office or public pressure mounts for or against certain measures.

Third, there is uncertainty about ecosystem dynamics. Policy frameworks need to respond to environmental changes that are difficult to predict because the effects of environmental disturbances are non-linear. If disturbances are minor and time-bound, systems tend to return to their previous equilibrium state; but thresholds exist beyond which systems may collapse (Scheffer

2009). Natural science research is thus needed to understand the inherent economic risks in ecosystems' dynamics and inform policymakers and investors.

Overall, uncertainty tends to be larger in green transformations than in ordinary market-driven transformations. Governments thus have a particularly important role in reducing uncertainties and related investment risks. They can do so by drafting roadmaps to augment investors' confidence in long-term policy targets. The EU's energy targets and its reduction targets for automotive fleet emissions are cases in point. Governments can also provide guarantees. Renewable energy laws in many countries combine guaranteed purchases from independent power producers with guaranteed minimum prices, known as feed-in tariffs. Also, they can anchor certain long-term targets in international treaties. All these measures help to lock polices in, shielding them from political cycles and increasing investment security.

On the other hand, given technological uncertainties, policy frameworks also need a certain degree of flexibility to respond to changing circumstances, such as new environmental risk assessments, emerging technological options or changing prices. The challenge is thus to find a good balance between providing 'directionality' and encouraging entrepreneurial experimentation (Mazzucato 2013).

4.5. ADDITIONAL POLICY INTERFACES AND NEED FOR POLICY COORDINATION

Often the green transformation goes far beyond the replacement of individual technologies. What is pursued is a transformative change of entire production systems, such as the energy system or the transport system. This requires simultaneous changes on several fronts including the development of various interdependent technologies and business models and the related adjustments of regulations and support systems. Such systemic change is unlikely to proceed smoothly without a proactively coordinating public agency. For example, no company would dare to invest in offshore wind parks unless other investors ensure the synchronized establishment of a grid that allows to bring electricity to the shore and further on to the main centers of demand. That, in turn, requires complex plan approval procedures involving affected communities as well as regulatory provisions for electricity transmission through various systems. Likewise, carmakers are unlikely to shift from fuel-driven to electric cars unless other specialised firms make parallel investments in batteries and charging infrastructure, and new technical standards are developed as well as credible policy road maps that signal the phase-out of fuel engines. Well-managed coordination processes with strong political backing are needed to bring such change about.

While the failure of markets to bring about simultaneous large-scale investments in complementary fields is one of the key reasons for adopting industrial policy in general, such coordination failure is particularly problematic when change is system-wide and transformative, as it is the case in the greening of economies. As economic subsystems tend to be interlocked, transformative change in one subsystem tends to have repercussions on others. When energy systems shift from fossil to renewable biofuel, it has unintended consequences on land and food prices; if dams are built to create hydropower, it affects water supply for agriculture; if agriculture shifts to organic, markets change for producers of fertilisers and agrochemicals.

Hence, new policy interfaces become relevant to understand the interdependencies and optimise the outcomes for all sectors of a society, especially civil society. Political decision-makers need to take various stakeholder interests into account when designing policies. This, again, is not a unique feature of green industrial policy, but it is a particularly relevant element of it, because stakeholders lobbying for the preservation of jobs provided by polluting industries are often better organized than environmental groups or social activists, for instance. The political feasibility of green economic reform therefore often depends on compromises among these interests, even though some compromises may reduce the policies' effectiveness in terms of environmental performance. Hence policies need to be co-designed by participants with strictly environmental interests and those helping to maximise social welfare, as well as those supporting economic or industrial interests.

4.6. THE MOTIVATION TO PROTECT NOT ONLY NATIONAL INTERESTS BUT ALSO GLOBAL COMMONS

The agenda of green industrial policy is partly driven by international agreements, such as the Paris Agreement, where governments have committed to decarbonise their economies; the Montreal Protocol on the protection of the ozone layer; and other treaties concerning fisheries management, marine and air pollution control, proper management of hazardous materials or genetic diversity of crops. All these agreements have a differential effect on industries: restricting the expansion of resource-using industries and/or forcing them to use product substitutes or to develop different technologies and business models, for example. They all serve to solve collective action problems at an international, often global, scale.

This is another important difference vis-à-vis traditional industrial policy. Normally, governments will try to implement the required policies in such a way that they enhance the productivity, competitiveness and employment potential of its domestic industries. Thus "...the benefits vest almost exclusively in the implementing country, and the costs are borne by foreign producers–a traditional mercantilist outcome" (Cosbey 2017, this volume). When it comes to green industrial policy, there are likely to be positive externalities for the global environment and for other countries. As pioneering countries develop solutions for environmental pressures, their industries will allow other countries to solve their domestic problems at a lower cost (Fankhauser et al. 2012). These spillover effects have important implications for the way we judge public subsidies. While in normal conditions, industrial policy should not enter into a competition on the basis of subsidies; a 'subsidy race' among nation states can be a good thing as it accelerates the development and global dissemination of green technologies (Rodrik 2014:471).

Hence, policymakers need to ponder the effects on domestic industry and global commons. Ideally, green industrial policy improves both in tandem, but outcomes differ in practice. Germany's solar policy was temporarily seen as a successful industrial policy in the traditional, national sense. A fairly high guaranteed feed-in tariff contributed to the diffusion of solar panels in the German market, and local companies reaped early mover advantages, becoming world market leaders and creating thousands of manufacturing jobs. But after a few years, Chinese low cost competitors started to crowd out the German industry, and many German solar panel manufacturers went bankrupt (Lütkenhorst and Pegels 2014). This led observers to criticise German solar policy as one that created a market but failed to build an industry (Paris Tech Review 2012). From a global perspective, however, Germany's support for the industry enabled the first large-scale photovoltaic module production that in turn brought unit prices down–by 80 per cent in the period 2009–2015 (IRENA 2016). The supply triggered worldwide deployment of this green technology. In terms of national industry, China was the main beneficiary (Pegels 2017, this volume).

More recently, a similar story is happening with electric vehicles, where China is the pioneer that accelerates the global diffusion of greener technologies. Here, the government heavily subsidises the shift from internal combustion to electric engines, thereby making China the lead market where new models are developed, tested and rolled out in mass production (Altenburg et al. 2017, this volume). Given that China is the world's largest automobile market and served largely by multinational carmakers, China's industrial policy is accelerating the cost degression of electric cars and batteries to the benefit of the rest of the world.

Currently, such positive spillovers from national policies to global green technology diffusion have mainly happened unintentionally. To accelerate the worldwide diffusion of technological solutions for managing global commons, more international technology cooperation is needed. This requires expansion of mechanisms that fund international research and development, knowledge sharing and technical assistance to developing countries, such as the Global Environmental Facility and the UNFCCC's Technology Mechanism.

5. CONCLUSIONS

Governments, those of developing countries in particular, are facing a dual challenge: they need to advance structural change towards higher productivity while at the same time decoupling human well-being and economic progress from resource consumption and emissions. This implies the need to better integrate industrial and environmental policies–rethinking the former from an environmental perspective and exploring how the latter can contribute to greater competitiveness and more and better jobs. This chapter shed some light on the policy options.

In the long term, there is no trade-off among social, economic and environmental objectives: there is no human development or economic success on an uninhabitable planet. In the short term, however, there are trade-offs to be considered. For example, pricing environmental goods puts an additional, but appropriate, burden on producers who have been able to externalize these costs in the past and may jeopardize their competitiveness and employment capacity. At the same time, moving to greener economies holds many benefits even from a purely economic perspective, as greater resource efficiency lowers costs, early movers may develop new markets, asset-stranding is avoided and new job opportunities open.

Governments need to understand the opportunities and pitfalls to minimise the costs and maximise the gains, striking a fine balance between environmental objectives and competitiveness, industrial development and job agendas. It should be noted that this is a classic political transformation project rather than a technocratic exercise. First, because finding the right balance of competing objectives and deciding among various alternative techno-institutional pathways implies value judgments; and second, because transformations always create winners and losers. Governments need to create consensus on the direction of change and facilitate compromises among stakeholders. This in turn presupposes a thorough understanding of interest groups and their power resources. When some elements of the transformation encounter strong resistance from interest groups, governments need to identify less contested no-regret options, such as resource efficiency programmes with quick economic returns or pollution control programmes with benefits for large parts of the society, to propel the transformation forward. Fortunately, there are already strong forces driving the green transformation, such as the decreasing price of renewable energy generation, an increasing number of environmentally conscious citizens ready to wield their voices and their buying power, lead firms in global value chains pushing for greener supplies, international treaties demanding greener standards and institutional investors pulling out of carbon assets.

Accelerating structural change always requires a proactive public sector. The case for industrial policies is theoretically very strong and backed by evidence. Public policies have a role in supporting research and development, subsidizing entrepreneurial cost discovery, coordinating complementary investments that need to be undertaken simultaneously and facilitating information sharing and technological learning. In these areas, social benefits tend to be much higher than returns to private investors, so that markets alone cannot provide socially optimal solutions.

When it comes to the urgent need to decouple human development from non-renewable resource consumption and pollution, market signals alone are even less effective. First, environmental costs are not sufficiently reflected in market prices, and second, the green transformation requires system-wide changes–such as radical redesign of the predominant energy systems–that cannot take place without well-coordinated interventions to deal with multiple coordination failures. As a consequence, green industrial policy is in many aspects similar to traditional industrial policy, but it has to come to grips with additional layers of complexity: The need to avoid negative environmental externalities requires specific policy instruments, such as cap-and-trade systems and environmental taxes. The urgency to phase out polluting technologies and replace them with green substitutes within short time frames calls for more comprehensive and aggressive research and development and technology diffusion programmes. The necessary restructuring of entire economic sub-systems presupposes long-term strategies spanning several decades that offer clearly defined interim targets and, where necessary, credible long-term subsidy schemes and financial guarantees. Furthermore, particularly comprehensive policy coordination and consensus-building mechanisms are needed to manage radical systemic changes at the interface of industrial and environmental policies. Thus as a rule, green industrial policy is more ambitious than most industrial policies of the past. This increases the risks of misallocation and political capture. We argue, however, that the long-term costs of not taking, or of delaying, action are much larger than the risks of losing part of the industrial policy funds to non-performing programmes and that there are proven policy design principles that greatly reduce the risks of ineffectiveness and capture.

Countries are likely to reap multiple benefits when they take a proactive stance and accelerate their green transformation in a way that combines social, economic and environmental objectives and when they design their policies according to the three basic principles of effective industrial policymaking. Well-designed green industrial policies are crucial not only for bringing economic development back into the safe operating space for humanity; they can also serve as an investment programme for long-term productivity gains.

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PART 2:

THE ECONOMIC AND SOCIAL CO-BENEFITS OF GREEN TRANSFORMATION

CHAPTER 2

WHAT CAN DEVELOPING COUNTRIES GAIN FROM A GREEN TRANSFORMATION?

Emilio Padilla

1. INTRODUCTION

This chapter reviews the reasons for developing countries to green their economies and to resist deferring action on environmental concerns for later phases of development. It first examines the relationship between economic growth and environmental pressures. The findings do not support a defence of growing first and cleaning later or a justification of inaction based on differentiated responsibilities for environmental degradation. These two arguments are elaborated in subsections 2.1 and 2.2, respectively.

The chapter then explores, in section 3, the different gains that environmental and green industrial policies may produce when designed to transform economies in developing countries. Significant synergies can build between some green policies and social and economic gains in developing countries, though there may also be trade-offs that require careful consideration.

2. THE RELATIONSHIP BETWEEN ECONOMIC GROWTH AND ENVIRONMENTAL PRESSURES

This section discusses two main arguments. First, a hypothesis based on the environmental Kuznets curve has frequently been used to support that economic growth will generate the solution to environmental problems, so emphasis on environmental and green industrial policies can be addressed later in developing countries. Second, developing countries' lesser responsibility for historical environmental degradation, especially for global problems, is used to suggest that poor countries should not make efforts to green their economies.

2.1. IS IT SMART TO GROW FIRST AND CLEAN UP LATER? THE ENVIRONMENTAL KUZNETS CURVE-ARGUMENT

The relationship between economic growth and environmental degradation is a very complex one. The debate on this relationship was dominated for many years by the hypothesis—based on an environmental version of the classic Kusnets curve—that emerged in the early 1990s with the seminal study of Grossman and Krueger (1991) on the potential environmental effects of the North American Free Trade Agreement. That study was followed by a series of empirical articles analysing the relationships on economic growth and environmental consequences for different pollutants and countries (Shafik and Bandyopadhyay 1992; Panayotou 1993).

SCALE EFFECT VERSUS COMPOSITION AND TECHNOLOGY EFFECTS

According to the environmental Kuznets curve hypothesis, economic growth increases environmental pressures at early stages of development; but, after a turning point, high per capita income levels enable societies to reduce their environmental impact. To explain this relationship, Grossman and Krueger (1991) identify three effects: scale, composition and technology. In this scenario, the size of the economy, the scale effect, would increase environmental pressures. At the same time, the environmental pressures would be reduced by the structural change that accompanies economic growth, the composition effect, and by ongoing technological improvements, the technology effect. If the composition and technology effects progress in the same direction and are strong enough to compensate the scale effect, a turning point could appear in the trend tracking environmental degradation and economic growth. Beyond that turning point, environmental degradation would decrease as the economy grows.

Assumptions about structural change of an economy explain the compositional effect: Industrialisation—the increased relevance of manufacturing and extractive activities and the mechanisation of agriculture—involves more intensive exploitation of natural resources and subsequent generation of waste. However, there is a point where the relevance of services starts to increase. The technology effect assumption is that technologies improve, in ways that bring environmental benefits, with economic development. Supposedly, in combination these two effects would reduce environmental pressure.

This argument has, however, several flaws. An increased share of services in total production does not necessarily entail a lower environmental impact. Some services demand inputs and pull emissions and material resources from other sectors. Such services include wholesale and retail trade, public administration, and hotels and restaurants, a sector strongly related to tourism activities (Alcántara and Padilla 2009; Piaggio et al. 2015). In addition, even though the proportion of services may increase, this does not mean that the number of industries producing goods will decrease with income growth. Therefore, the composition effect may reduce the pressure per unit of production but not the absolute environmental pressure (Roca et al. 2001). That is why, it may lead to a reduction in the intensity of resource use or emission per unit of output, a relative decoupling of environmental pressure from economic growth, but not to a reduction of total environmental degradation, which would be considered an absolute decoupling from economic growth.

As for the assumptions about technological change, any positive consequences for the environment following economic growth will only happen with the appropriate policies in place. Without these, new technologies may often result in a higher rate of environmental degradation: a salient example is how improvements in fish location technology resulted in devastation of fish populations. In addition, while technological improvement may lead to a more efficient use of resources in productive processes, sometimes they involve new productive processes presenting new environmental pressures, as has resulted from hydraulic fracturing, or fracking, of geologic formations to allow oil and gas extraction. Even in the case of efficiency improvements, the final effect on the environment is uncertain, due to a tendency of consumers to use more of a resource when the services obtained from it become less expensive through improved efficiencies, called a rebound effect (Schipper and Grubb 2000; Gillingham et al. 2013).

ENVIRONMENTAL QUALITY AS A LUXURY GOOD

Another interpretation of the environmental Kuznets curve hypothesis presents environmental quality as a luxury good (Selden and Song 1995; Martinez-Alier 1995). In other words, as incomes increase, demands for environmental quality increase and environmental degradation will be remedied. This explanation ignores that poor populations, disproportionally composed of women, often directly depend on the quality of environmental resources to meet their basic needs (UN 1995). Another flaw of this approach is that environmental quality is not a private good that can be bought in the market. Instead, it depends on environmental policies that are decided in the political arena (Roca and Padilla 2003). Therefore, environmental quality strongly depends on countries' political systems and the strength of their institutions.

EMPIRICAL EVIDENCE

The empirical evidence for the hypothesis is not conclusive. While the environmental Kuznets curve seems more relevant to local pollutants with clearly perceived consequences for health and local environments, such as particulate matter or sulphur dioxide, it seems less applicable to global pollutants. There is empirical evidence that different countries follow different paths in this relationship, so what is found to hold for a group of countries may not be valid for the path followed by individual country (Piaggio and Padilla 2012). Some authors also argue that the environmental Kuznets curve could appear to improve in developed economies because they have exported their polluting activities to developing countries (Suri and Chapman 1998).

IMPORTANCE OF ENVIRONMENTAL POLICIES

Even in the case of evidence supporting the hypothesis, the level of pollution estimated to produce the turning point is usually too high for most countries to risk and would deliver unbearable environmental degradation with irreversible damages if developing countries followed the projected path (Stern et al. 1996). Many environmental damages cannot be reversed and so the previous level of environmental quality cannot be recovered (Arrow et al. 1995). Examples of these irreversible environmental losses include soil erosion, aquifer destruction, or extinction of species or ecosystems. Other problems with unpredictable consequences include irreversible changes to the Earth's climate system, with associated impacts that will confound us for centuries at a minimum.

Therefore, the solution to environmental problems requires appropriate and prompt political action because economic growth alone will not solve environmental problems. In fact, one of the most relevant conclusions from the debate on the environmental Kuznets curve is precisely the importance of resolute environmental policies in making economic growth compatible with sustainable development (Ekins 1997). Appropriate environmental policies can determine less damaging paths for the industrialisation of developing countries, paths than can benefit from lessons learned and avoid mistakes experienced by countries that industrialised at an earlier stage (Dasgupta et al. 2002). Thus, appropriate environmental policies can help less developed countries to pass over environmental degradation phases. Just as some societies have skipped the phase of using landline telephones or desktop computers, smart policies will move directly to the use of clean technologies and efficient processes, without repeating polluting processes and mistakes of environmental degradation that industrialised countries experienced. These cleaner technologies and efficient processes have already been researched, developed and demonstrated in more developed countries, so they are ready to be adopted and adapted to developing countries' needs.

2.2. HISTORICAL RESPONSIBILITY FOR ENVIRONMENTAL DEGRADATION?

Inequalities in the contribution to environmental degradation have served to suggest that less developed countries should grow first and leave environmental concerns for a more affluent future. These differences in the contribution to environmental degradation have been referred to as historical responsibility, or differentiated responsibility, for the current degradation of natural resources and environmental services: developed countries industrialised through intense consumption of fossil fuels, minerals, forests, food and fibre and other natural resources. They also burdened the carrying capacity of the environment by dumping waste into the air, water and land. In contrast, developing nations have started only recently to industrialise. As well, given this legacy, today's poorer countries are under strong pressure to reduce poverty and improve the livelihoods of their citizens. Therefore, some proponents of the concept of differentiated responsibilities argue that developing countries are not in the position to make economic sacrifices for environmental reasons—and that it would not be fair to ask them to. However, neither limited historical liability nor pressing economic needs are good reasons for developing countries to reject development and implementation of sound environmental policies.

First, projections and experience suggest that many developing countries are most threatened by global environmental problems (IPCC 2014). Therefore, they should have a strong interest in the strength and enforcement of global environmental agreements so the remedies to these problems can be applied. However, to succeed, these global environmental agreements need developing countries to participate. This can be well illustrated with the case of climate change: it is now evident that no international agreement can be effective if emerging economies do not take part. This fact became explicit in the negotiations that achieved the Paris Agreement, to which they committed. The same evidence of commitment to finding solutions applies for most global environmental problems, such as biodiversity loss or ozone depletion. Global environmental agreements can also provide additional benefits for developing countries.

Second, local environmental pressures—such as air and water pollution, soil erosion and resource depletion—produce immediate repercussions on the welfare of developing countries' citizens, due to their higher dependence on natural resources for direct consumption and income generation and their greater vulnerability to environmental risks. Future development cannot be sustained by following the same path of environmental degradation as the one adopted by industrialised countries.

The next section analyses the opportunities that may be associated with green industrial policies and the actions oriented to green the economy of developing countries.

3. THE BENEFITS THAT INTRODUCING GREEN INDUSTRIAL POLICIES AND TRANSFORMING TO A GREEN ECONOMY WILL DELIVER TO DEVELOPING COUNTRIES

As subsection 2.1 demonstrated, the 'grow first, clean up later' argument rests on weak empirical grounds, has several conceptual flaws, and ignores the risk of irreversible ecological damages and dependence on natural resources, especially by the poor. However, a concern of many developing countries is that the cost involved to achieve a green transformation is too high and cannot be afforded by low-income countries with more pressing needs than greening their economies. However, this need not be the case. Instead, many policy measures are affordable and deliver significant co-benefits in association with transforming to a green economy. This can be attributed to a large part to market failures, such as environmental or knowledge externalities, for example, or to government failures, such as subsidies to environmentally harmful activities. These failures lead to poor natural resource management, industry inefficiencies, or unexploited opportunities in the development and diffusion of industries or technologies. Correcting these problems pays off from an economic point of view for consumers, but also for industrial producers. Governments should explore the potential synergies between development and environmental protection that would facilitate their particular transition to a sustainable development path. The following subsections describe twelve good reasons for considering the introduction of green industrial policies and transforming to a green economy.

3.1. ENVIRONMENTAL IMPROVEMENT BRINGS HIGH QUALITY ENVIRONMENTAL GOODS AND SERVICES AND BETTER HUMAN HEALTH

The first obvious benefit of policies promoting a green transformation of the economy is to have better access to high quality environmental goods and services and better conditions for human health. The welfare of low-income populations in developing countries is closely related to their access to, and the quality of, environmental goods and services and they are therefore the most seriously affected by environmental degradation (Broad 1994; Jehan and Umana 2003; Bowen and Fankhauser 2011; World Bank 2012). In addition, the lack of resources and proper institutions limits these citizens' capacity to react and adapt to environmental degradation and makes them more vulnerable to it (IPCC 2014). Lack of clean freshwater availability and health problems associated with pollution are clear examples of how environmental degradation imposes a high burden on the welfare of poor populations. According to the World Health Organization (2016a), around 3 billion people in low and middle-income countries cook and heat their homes using solid fuels of biomass and coal, highly inefficient sources that produce indoor pollution. As a consequence, 4.3 million people a year die prematurely (WHO 2016a).. This affects especially women and children, due to their gender roles and household responsibilities, such as cooking and spending a lot of time indoors (World Bank 2003). Measures that provide access to clean fuel and technologies could reduce this death toll at a moderate cost and improve the welfare and the economy of these low-income populations. Estimates suggest that, in addition, outside air pollution caused 3 million premature deaths worldwide in 2012, with 88 per cent occurring in low and middle-income countries (WHO 2016b). In general, measures to improve air quality, as well as the availability and quality of fresh water, will reduce negative health effects that could help to increase labour force productivity (OECD 2001).

3.2. DETERIORATION OF ENVIRONMENTAL RESOURCES AND SERVICES UNDERMINES THE POTENTIAL FOR FUTURE GROWTH OF DEVELOPING COUNTRIES

Degrading the environment for the sake of increased economic growth is not a rational policy because economic growth is highly dependent on the availability of natural resources and on the environment's capacity to assimilate waste. This is particularly true for developing countries, given their citizens' dependency on natural resources and services for direct consumption and income generation. Environmental degradation is already imposing high costs on several developing countries: averaging at 8 per cent of GDP across a sample of countries that represented 40 per cent of the developing world's population in a World Bank analysis (World Bank 2012). An improvement in the management of natural resources and services can certainly increase their economic productivity, such as when the stock of a renewable resource has recovered, and can contribute to improve both the environment and economic opportunities. Tackling market and government failures in natural resource management would improve environmental quality, worker productivity and public welfare.

3.3. MEASURES TO AVOID THE OVERUSE OF COMMON-POOL RESOURCES WILL INCREASE RESOURCE PRODUCTIVITY

Environmental goods can be common-pool resources. These are limited resources that are shared, when there is rivalry over consumption and it is difficult to exclude users. These resources frequently suffer from the open access problem: there are no clear owners and there is no management system restricting the use of the resources (Ostrom 1990; Aguilera 1994). When the resource is overexploited, the benefits accrue to those who overused the resources and the costs accrue to those who did not. Many low-income people around the world depend on common-pool resources in the form of fisheries, forests or pastureland. Proper management of these common-pool resources would reverse their deterioration and increase their economic productivity. According to the nature of the resource and the institutional framework, different measures could combine to induce proper management. The enforcement of property rights or of clear social norms is usually required for a solution.

In some cases the introduction of economic incentives can help to recognise the value of the resource and its scarcity. An example of these incentives is the payment for environmental services, an approach that can reverse degradation of ecosystem services and help alleviate poverty (Pagiola et al. 2005), if applied in an appropriate manner. However, economic incentives are not always the solution: In some cases they may conflict with existing values and social incentives for conservation, so any such incentives should be carefully adapted to each context. In the case of fisheries, the open access problem has led to overfishing and the exhaustion of resources, with a strong decrease in the yield and associated jobs and income. An efficient way to manage the problem of overfishing would be through the distribution of tradable quotas–limiting total resource capture. This tool seems highly effective in preventing fisheries collapse and increasing the productivity of the resource. Costello et al. (2008) and Heal and Schlenker (2008) found empirical evidence supporting this hypothesis through the analysis of more than 11,000 fisheries. Chu (2009) found evidence of a positive effect in 12 of the 20 analysed fish stocks where individual tradable quotas were implemented. These findings suggest that tradable quotas can be a beneficial element in the management of some fisheries while alternative or complementary measures would be required in others. Another example that seemed to deliver positive results is the Chilean Jack Mackerel Individual Transferable Quotas System (Kroetz et al. 2016). Some authors suggest, however, that community rights-based management that limits the harvest would be more successful in contributing to poverty alleviation in the context of small-scale fisheries in developing countries (FAO 2005).

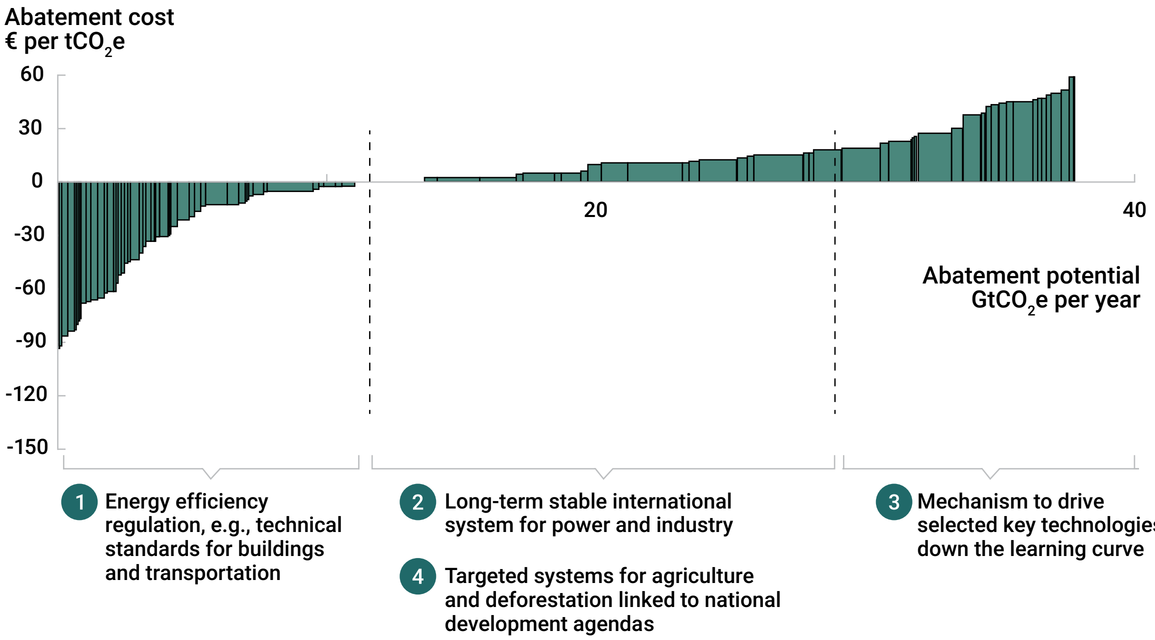
These are examples of measures that, besides their environmental benefit of resource sustainability, pay for themselves in economic terms by solving the previous mismanagement of environmental resources. Hence, they can be seen as no-cost measures, at least over the longer term. In addition, achieving more stable and sustainable harvests could make the development of resource processing industries more feasible.

3.4. MEASURES TO INCREASE RESOURCE EFFICIENCY OFTEN PAY FOR THEMSELVES

Key improvements from the application of market instruments and complementary measures designed for green economic transformations are found in environmental efficiency gains. These are realized as lower resource use and lower pollution per unit of production that also may produce significant short-term economic gains. Improvements in production processes that save resources can pay off the initial costs in a short period of time. In some situations resources are simply wasted, as many economic processes are inefficient due to market distortions, inertia, lack of proper information or bad management. In many industrial processes, existing technologies could reduce energy consumption and pollution. These savings could provide net economic benefits rapidly, besides having a positive environmental impact. According to the World Bank (2010) energy efficiency investments can produce a triple dividend: greater energy savings, fewer emissions and more jobs. Worldwide, every additional dollar spent on energy efficiency saves more than twice that investment on the supply side with higher savings in developing countries (Bosseboeuf et al. 2007; World Bank 2010). Thus, energy efficiency can present not only a 'no-cost' measure in many cases but often constitutes a 'negative-cost' thus saving money over the mid to long-term (Figure 2.1).

There are great potential savings to be gained through energy efficiency in buildings. This is a particularly powerful point for developing countries, as their building standards are yet to be formulated and they will soon be building most of the infrastructure they will be depending on for the next few decades (World Bank 2010). In the case of manufacturing, the potential for energy savings is significant for developing countries because of their current lower efficiency levels and early phase of industrialisation. According to the IEA (2008), energy consumption in the industrial sector could be reduced by 20 to 25 per cent with existing technologies and best practices contributing to growth.

Figure 2.1: Key areas of regulation



Source:

In their report "Pathways to a low-carbon economy: Version 2 of the global greenhouse gas abatement cost curve", McKinsey and Company identify four key areas of regulation to reduce CO_2 emissions at the lowest cost. The graph demonstrates that Policy area (1) Energy efficiency regulation will result in a net economic benefit or 'negative cost' for the economy: This is the case as energy efficiency regulation, such as standards or technical norms, can overcome market imperfections that currently prevent the private sector from realising energy efficiency measures that would result in a net profit (for which the cost savings of reducing energy consumption are higher than the initial investment in energy efficiency measures) (McKinsey & Company 2009).

Various measures in the power sector could pay for themselves, of which one is the utilisation of off-grid electricity systems. Rural areas in low-income countries have scattered demand and low consumption levels that challenge the logic of providing grid electricity. Off-grid solar power systems can provide modern energy services at lower costs than diesel generators, while reducing the noise and fumes (IFC 2007; Bowen and Fankhauser 2011). Very small scale units can replace commonly used kerosene lanterns improving indoor air quality and reducing fire hazards (REN21 2016).

3.5. ONCE LOCKED IN TO RESOURCE-INTENSE AND POLLUTING ENERGY AND TO UNSUSTAINABLE URBAN INFRASTRUCTURE DEVELOPMENT, COUNTRIES WILL FIND IT DIFFICULT TO SWITCH TO GREEN PATHWAYS IN THE FUTURE

A way to improve environmental and economic efficiency is through better urban planning, avoiding city sprawl models, because more dense and compact city layouts reduce energy consumption and pollution, especially in transport (Rickwood et al. 2008; OECD 2012a). Poor countries are still developing most of their infrastructure and are rapidly urbanising. Besides the tragedy of irreversible environmental damages, the economic costs of greening the economy at a later stage of development may be too high due to infrastructure, sectoral and technological lock-in. The costs of replacing long-lived fossil-fuelled machinery and infrastructure or of reversing inefficient urbanisation models may be too high. Present technological and infrastructure decisions may lock countries into a high-carbon economy that can involve much greater costs in a future world of decarbonisation (World Bank 2012). The risk of stranded assets, relinquished because of sudden or premature write-downs, devaluations or conversion to liabilities, as well as divestment pressures, highlight these financial pressures and point towards the benefits of a low-carbon transition (Baron and Fischer 2015; Caldecott et al. 2016).

Focusing on economic growth, following the same path as developed countries and greening later would be much more costly than following a path now to transform to a green economy. Developing countries have the advantage, from the environmental point of view, that so much of their infrastructure is yet to be built, so they can use current knowledge of best practice to minimise environmental and economic costs in their development paths. They can take advantage of current knowledge to avoid carbon intensive development and to adopt cheaper, cleaner, and more efficient production options. This would also avoid the high costs of replacement as these carbon-intense technologies and processes become obsolete, likely long before they break down.

3.6. REDUCING INEFFICIENT AND HARMFUL INCENTIVES CAN IMPROVE THE ENVIRONMENT AND PROVIDE POSITIVE ECONOMIC IMPACTS

In some cases governments introduce inefficient, or perverse, incentives that encourage or accelerate environmental deterioration. A direct way to improve the environment while enhancing economic efficiency is by eliminating the incentives to overexploit resources or to produce and consume polluting processes. These perverse incentives are highly inefficient as they distort market values away from the actual values of environmental resources and the material costs of environmental degradation.

These incentives often take the form of subsidies and are maintained because of the pressure of special interest groups or the fear that eliminating them would lead to social unrest. As an example, world fisheries subsidies were estimated at around US$ 35 billion in 2009 (Sumaila et al. 2016). According to the International Monetary Fund, fossil fuel and electricity subsidies reached US$ 4.9 trillion in 2013 and 5.3 trillion in 2011, or 6.5 per cent of that year's global GDP (Coady et al. 2017). Other types of support that lead to the overuse of natural resources include mineral extraction, water irrigation and agriculture. Dobbs et al. (2011) and the World Bank (2012) estimate the total annual economic support to natural resource overexploitation to be between US$ 1 trillion and US$ 1.2 trillion annually. Eliminating fossil fuel subsidies alone would have reduced fossil fuel air pollution deaths by 55 per cent, raised revenue by 4 per cent, and increased social welfare by 2.2 per cent of global GDP in 2013, while at the same time cutting global carbon emissions by 21 per cent (Coady et al. 2017). Some estimates suggest that three quarters of global energy subsidies are provided by the governments of developing countries (Coady et al. 2017).

In addition to their direct damage, energy subsidies lock economies into inefficient technologies that will be more difficult and costly to replace in the future. This possibility makes perverse incentives even more toxic for the futures of developing countries, where infrastructure is to a great extent still to be built, despite the immediate attraction they offer to quell potential social unrest. While the poor are credited as the source of such unrest, the actual benefits of these perverse incentives most often accrue to the elites in developing countries, perpetuating inequities (Clements et al. 2014). Examination of evidence gathered between 2005 and 2009 in twenty developing countries found that the richest 20 per cent of households capture an average of six times more in fuel subsidies than the poorest 20 per cent (Arze del Granado et al. 2012).

The environmental and economic benefits of subsidy reform have been widely discussed (Coady et al. 2017). However, with a restructuring of benefits, there will always be winners and losers and sometimes any change can incite political and social resistance. Historically, and more recently through the networks of social media, this resistance arises from misleading information about the value of the environmental damage and the need for subsidies. The most responsible remedy is better information presenting the short and long term benefits of the reforms, and explaining the damages imposed by perverse incentives especially in terms of inequity and injustice. To reinforce the message, reforms should also entail compensation measures targeting the groups most affected, especially lower and middle-income populations, so that the reduction of subsidies is not seen as an unfair policy (Jakob et al. 2015). In return, newly available public revenues could be used to finance programmes aimed to increase political acceptance of these reforms, including information campaigns, social cushioning or additional measures to facilitate the transition to a greener economy (Clements et al. 2014; Jakob et al. 2015).

3.7. DEVELOPING COUNTRIES MAY LEVERAGE NEW COMPETITIVE ADVANTAGES IN ENVIRONMENTAL GOODS AND TECHNOLOGIES BY ADAPTING/PRODUCING GREEN PRODUCTS

Several emerging economies and developing countries have been very successful in developing new exporting sectors based on green products. Specific industrial policies have been successfully implemented in China, Brazil, Ethiopia, Indonesia, Tunisia, Mexico or Morocco to develop new sectors with green aspects (OECD 2012b). For the most part, developing countries cannot afford the risk at the cutting edge of new technologies. However, they can adapt the best available technologies to their circumstances and promote the development of green sectors with the appropriate support, leading to increased exports and jobs. Green industrial policies should focus on untapped but clear comparative advantages, and many developing countries have very rich natural endowments that could inspire development of green industries, such as solar energy in North Africa (Vidican Auktor 2017, this volume). While high-income countries have traditionally pioneered green innovations, developing countries are catching up, particularly East and South Asia as represented by China and India (Dutz and Sharma 2012; World Bank 2012). In 2010, green goods and services constituted 3.4 per cent of exports from developing countries compared to 6 per cent from high-income regions (Dutz and Sharma 2012). The current production structure of developing countries already indicates that they could catch up gradually: One indicator for this is the share of 'green and close-to-green products' that amounted to about 13 per cent of developing countries' exports in 2010, compared to about 15 per cent in high-income countries. Compared to the export percentages for green goods and services in developing countries and high-income countries, the shares for green and close-to-green product exports are much more alike in the two country groups (Dutz and Sharma 2012).

This indicates substantial opportunity for developing countries in regard to increasing export volumes of environmental goods. Many opportunities are linked with the export of green goods and services, including tapping into a growing market of environmentally aware customers in high-income countries. Countries should also bear in mind that environmental awareness and international policy stringency grow over time, thus increasing demand for green products and services. Not investing in that growth market might therefore be associated with high opportunity costs. On the risk side, there may be the possibility of losing part of domestic demand, at least short-term, if this reorientation of production involves changes in cost.

3.8. DEVELOPING COUNTRIES CAN SIGNIFICANTLY PROFIT FROM THE ADAPTATION AND DEPLOYMENT OF ALREADY PROVEN GREEN TECHNOLOGIES

Some emerging economies can successfully compete in green innovation sectors. However, lower-income countries may not be in the position to invest in cutting-edge green innovation research and development due to their lack of resources, human capital and technological capacity. They may rather focus on facilitating the diffusion and adaptation of existing green technologies, to make their own industry more competitive and to reduce environmental impacts. There is much to be gained in promoting the adoption of green innovation and technologies. To accelerate this process of adoption, adaptation, and deployment, international openness is a relevant factor (World Bank 2012). This requires trade and investment policies that encourage the import and deployment of foreign green technologies. Imports play an important role in transferring the green technology embodied in green products. Foreign direct investment also plays a relevant role in technology transfer (Moran 2015). To facilitate the adoption of green technologies it will be necessary to build local receptivity in the form of capacity development. To maximise the co-benefits obtained in the adoption of developed green technologies, capacity development should be customised to local needs and environments (World Bank 2012). Low-income countries should also focus on innovations that can be adapted to meet the needs of poor consumers at very low costs per unit (World Bank 2012). These include formal or informal innovations that seek to provide more product with less resources for more people (Prahalad and Mashelkar 2010; World Bank 2012). A good example is the wide adoption of off-grid solar electricity enabled and made affordable through business models based on responsive community-oriented customer service, mobile phone credit accounts, units that can be de-activated remotely upon default and profit gains as the customer pool increases in volume (REN21 2016).

3.9. GREEN ENERGY POLICIES INCREASE ENERGY SECURITY, REDUCING THE VULNERABILITY OF ECONOMIES TO OIL PRICE SHOCKS AND DEPENDENCE ON FUEL IMPORTS

According to Awerbuch and Sauter (2006), oil price increases and ongoing instabilities depress economic growth by raising inflation and unemployment and devaluing financial and other assets. The deployment of renewables could help countries to avoid costly economic losses by displacing fossil fuels.

Increased efficiencies and renewable energy sources provide additional co-benefits by increasing energy security and reducing the vulnerability of economies to oil price shocks as well as the dependence on fossil fuel imports.

3.10. POSITIVE EMPLOYMENT EFFECTS DUE TO GREEN SECTORS AND TECHNOLOGY INSTALLATION AND SERVICING MAY PRODUCE MORE DECENT JOBS AND PROVIDE A POSSIBLE DOUBLE DIVIDEND

Green sectors and technologies are likely to be more labour-intensive in the short term and then to provide more jobs in total over the long term, so the change in focus from conventional to renewable energy sources could also create jobs (Fankhauser et al. 2008). Job creation could also increase through public investment that develops green production and technologies. There may also be a double dividend when changing from taxing labour to taxing environmental damages—an environmental benefit plus an increase in labour demand resulting from environmental fiscal reforms that make labour cheaper relative to energy (Pearce 1991; Schlegelmilch et al. 2017, this volume).

The change to a greener economy may also involve transition costs in terms of employment when the induced change in relative prices temporarily leads to a situation in which polluting industries and jobs are phased out while new green alternatives emerge incrementally (World Bank 2012; UNIDO and GGGI 2015).

3.11. NOT PARTICIPATING IN INTERNATIONAL ENVIRONMENTAL AGREEMENTS AND FOLLOWING THE HIGH-POLLUTION DEVELOPMENT PATH COULD UNDERMINE THE LONG-TERM POTENTIAL FOR EXPORTS AND INDUSTRIAL DEVELOPMENT OF DEVELOPING COUNTRIES

More stringent environmental policies in the international context may have a series of consequences for developing countries. Some governments are concerned that enforcing environmental policies in their countries could affect the external competitiveness of their industry. In some cases, pressure from industry lobbies have led to introduction of exemptions to resource or pollution-intensive sectors, which introduce distortions and clearly reduce the efficiency and effectiveness of environmental policies (Ekins and Speck 1999; Baranzini et al. 2017). An option to deal with competitiveness concerns that is gaining weight in the academic and policy debate on international environmental agreements is to introduce trade sanctions on those countries not adopting similar environmental measures. These could take the form of compensatory taxes, such as border tax adjustments. In case these measures were generalised, this could induce exporting developing countries to adopt similar environmental standards to avoid sanctions. However, imposing these kinds of sanctions on developing countries is hardly justifiable on ethical grounds if there are not compensatory—or environmentally motivated—transfers from developed countries to developing ones.

As more stringent environmental policies, green industrial processes and market preferences for green production and products become widespread in industrialised economies, sticking to polluting economies may reduce opportunities for that developing country to export to a developed country market. If more strict environmental standards are adopted in developed nations, these are likely to be imposed on imported products as well, with the same effect on exporting opportunities of developing countries that do not make adequate efforts to green their industries.

In the specific case of international climate agreements, countries have incentives to free ride, as climate policies can be considered a public good. That is, free riders will benefit from the reduced impacts of climate change, while not making any effort to reduce their own emissions. To solve this problem, an increasingly popular idea is that there should be mechanisms to avoid the free riding of those countries not participating in climate agreements. One example of this is the proposal made by Nordhaus (2015) of a 'climate club' in which those countries participating in the global agreement could impose trade sanctions to those not participating, in such a way that the incentives to free ride disappear. However, as stated by Nordhaus (2015) low-income countries cannot be expected to match commitments of rich countries, so they should only assume the obligations of club membership once they pass to the middle-income group. Another proposal in climate policy discussions is that these sanctions could take the form of carbon border tax adjustments, in such a way that imports from free riding countries could be charged according to their carbon content as if they were subject to a similar policy (Lockwood and Whalley 2010) or similar measures, such as making them buy emission permits, oriented to 'level the carbon playing field' (Houser 2008).

Various studies analyse the design of carbon-motivated border tax adjustments and how they could be made consistent with WTO rules (Cottier et al. 2009; Mattoo et al. 2009; Jakob et al. 2014; Rocchi et al. 2015). These measures could eliminate the incentives to free ride and are defended on the grounds of avoiding negative competitive effects of carbon pricing in energy and emission-intensive industries. These measures therefore help to level the playing field for green and low GHG products and provide an incentive for countries to invest in their green industrial capacity as part of global value chains.

In this context, not participating in those agreements and following a high-carbon development path could undermine the long-term potential for exports and industrial development of developing countries. Early adoption of green industrial policies in developing countries' economies and an early green transformation could provide countries with an early mover advantage as regards low-carbon industrial capacity and the production of environmental goods and services. It can also reduce costs of transition at a later point and avoid costs associated with trade-related policy measures of importing countries, such as carbon tax equalisation or similar measures.

3.12. INTERNATIONAL ENVIRONMENTAL AGREEMENTS CAN ALSO INVOLVE FINANCING OPPORTUNITIES AND TECHNOLOGY TRANSFERS FOR DEVELOPING COUNTRIES

Developing countries have significant opportunities for low cost reductions of greenhouse gas emissions, particularly from agricultural and deforestation activities and other land use change (Bowen and Fankhauser 2011). Efficiencies alone could encourage developing countries to minimise the global costs of mitigation. Flexible mechanisms, such as the clean development mechanism, allow developing countries to obtain funds from richer countries for projects that reduce emissions, mainly in the energy and manufacturing sectors, or as payments for reduced emissions from deforestation and forest degradation. These schemes help achieve global reductions at lower costs, because they are implemented in developing countries, and thus make sense for countries with binding obligations. They also involve additional financial, technological transfer and capacity development support required for successful implementation that can also facilitate the transformation of the energy and manufacturing sectors of the host developing countries. These mechanisms can provide incentives for developing countries to participate in climate agreements, and motivate developing countries to expedite the green transformation of their industries. International carbon trading could initiate countries to follow a low-carbon development path and provide gains to those performing well (Bowen and Fankhauser 2011). Global climate agreements must also include climate-finance for developing countries to help their mitigation and adaptation efforts and to build their resilience to climate change. The Paris Agreement indicated the non-binding plan will provide US$ 100 billion per year for the period 2020 to 2025 to developing countries for decarbonisation, including technology transfers, and for adaptation measures. This amount will be increased after this period. The fund, and its eventual increase, argues in favour of decarbonisation measures and in environmentally sound adaptation and capacity building in developing countries.

A successful example of the implementation of a global agreement for another global environmental problem is the Montreal Protocol on Substances that Deplete the Ozone Layer. This protocol was signed in 1987 and ratified by 197 countries, most of them developing countries. Together with the original Vienna Convention for the Protection of the Ozone Layer, they became the first UN treaties to achieve universal ratification (UNEP 2014; 2015). The success of the Montreal Protocol, which induced a transformation in the manufacturing processes of the involved industries, has much to do with the special treatment that it gives to developing countries: They were given longer periods for meeting reduction targets and provided with means to do so, with the establishment of the Multilateral Fund for the Implementation of the Montreal Protocol in 1991 (Brander 2013). This fund provided financial assistance to developing countries for meeting their mitigation targets through projects oriented to replace polluting technologies. The Multilateral Fund provided a strong incentive for developing countries to join the Protocol and implement measures that reduced the use of ozone-depleting substances. Other factors contributed to successful implementation of the Montreal Protocol, including the availability of affordable alternatives and the existence of trade sanctions that made possible punishments for non-adherence credible.

Another important finance tool that has provided incentives to developing countries to participate in various international environmental agreements is the Global Environment Facility (GEF 2016). The fund is now a partnership of 183 countries, multilateral implementing agencies, organizations and the private sector. The fund was created to promote sustainable development and the protection of the global environment by providing funds for the development of projects with environmental benefits, and has been indispensable to facilitate the participation of developing countries in various international agreements.

Finally, the Green Climate Fund was established in 2010 by 194 countries party to the United Nations Framework Convention on Climate Change (UNFCCC) as a financial mechanism of the UNFCCC supporting the global response to climate change. Its resources are allocated to low-emission and climate-resilient projects and programmes in developing countries. Developed countries formally agreed to jointly mobilise US$ 100 billion per year by 2020 (GCF 2016). To receive any of these funds, and the development opportunities they offer, developing countries must be parties to the relevant multilateral environmental agreements.

4. CONCLUSIONS

A review of the arguments that are usually made against the application of environmental and green industrial policies in developing countries shows that these neglect important information. Neither the belief that economic growth alone will automatically lead to the best possible future nor the differentiated responsibilities between industrialised and developing countries for current environmental pressures offer persuasive arguments for rejecting the adoption of environmental and green industrial policies. In addition, besides the environmental improvement that can be obtained through these policies, there are a series of potential co-benefits for developing countries in terms of welfare enhancement and social and economic gains. Policies should be designed in an integrated manner, taking account of a country's specific circumstances, to maximise gains and co-benefits and manage potential risks.

If some green policies are win-win options, why are they not developed at a more rapid pace? First, various government policy and market failures require appropriate policy counter measures to neutralize them (World Bank 2012; Lütkenhorst et al. 2014). Second, implementing the appropriate measures is particularly challenging in developing countries. Developing countries face several economic and institutional limitations that can impede success. Some green industrial policies that are specifically designed to support particular industries or technologies require good governance of institutions, with the capacity to avoid rent-seeking and political capture by vested interests. These measures include feed-in tariffs for renewables, tax breaks for innovative firms or green public procurement. Public sector efforts face huge risks of failure from interest group pressure, rent-seeking behaviours or imperfect information, problems that lead to outcomes favouring specific groups rather than society as a whole (Pegels 2014; Rodrik 2014).

Policymakers should also be able to eliminate support programmes once they are no longer justified or accomplishing their objectives (World Bank 2012). Some policies that promote promising green industries and technologies could fail if these problems are not addressed adequately and appropriately. In addition, several green industrial policies require short-term investments that provide benefits only over the long term. The lack of financial institutions able to support such investments hinders their implementation in low-income countries. International finance and institutional support may be required to facilitate the success of green transformation processes in low-income countries.

Each country should assess the opportunities of applying green policies in its particular context, balancing the expected benefits against the potential risks. Moreover, each country should choose its own path of green transformation. This involves customising choices about sequencing and prioritizing measures that yield the highest short-term benefits, such as energy efficiency improvements or a proper management of natural resources. These customised choices could also lead to fewer or no regrets, such as efficient infrastructure construction that forestalls later replacement costs. Justifications for and potential benefits of the policies should be clearly identified for all stakeholders. Putting a price on pollution helps to reduce environmental problems and pressures, but it is not enough. Each instrument and mechanism should be combined with different measures according to the particular context. The potential costs of promoting innovative but unproven technologies may be great, so green industrial policies are less risky when they focus on technologies that have been tested elsewhere and adapted to the local situation or when they complement untapped comparative advantages that are readily observable. Each developing country should balance the costs of early action against the costs of lock-in and should follow a greening path appropriate to its specific needs.

Finally, the international context can play an important role in the definition of environmental policies and the development paths of developing countries. A context of more stringent environmental policies in developed countries can produce a variety of results for developing countries. For developing countries to succeed in following a clean development path, it is important that developed countries support them by providing the appropriate financial mechanisms. Some mitigation measures will require international finance to facilitate implementation. Help from the international community to facilitate provision of proper financial instruments, institutional support, or technology transfers may be crucial to convert potential gains into actual ones.

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CHAPTER 3

GAINING COMPETITIVE ADVANTAGE WITH GREEN INDUSTRIAL POLICY

Stefan Ambec

1. INTRODUCTION

Sustainability should be considered an integral part of the economic development process. Economic growth is often associated with pollution and ecosystem degradation, conditions that threaten human health and economic activities that rely on natural resources. Despite this feedback between poor environmental quality and the economy, policymakers are generally reluctant to impose more stringent environmental regulations on firms. They fear that it might erode firms' competitiveness, slowing down the country's economic development process.

A dominant opinion concerning environmental protection is that it adds cost to firms. According to this opinion, reducing the pollution from production processes requires that firms replace dirty inputs with cleaner but costlier ones. This may involve a switch to more expensive technologies or investment in devices that reduce or remedy polluting emissions, treat their waste, recycle water, or improve energy efficiency. All these strategies add new expenses to their balance sheets. We argue that such expenses can nevertheless turn out to be profitable in the long run.

The aim of this chapter is to review economic arguments and to show that the additional cost of environmental protection can lead to a competitive advantage for firms. This approach maintains that green policy can boost a firm's competitiveness while improving environmental quality. Four paths are distinguished by which green policy might enhance competitiveness. First, green standards and certifications enable firms to differentiate their products from those of their competitors. Section 2 explains why this product differentiation strategy can be profitable and what the role of public policy can be. Second, firms can make money by selling and adopting green technology. As explained in section 3, this argument particularly applies to environmentally sound technologies that are bought by developed countries due to energy mandates or financed by carbon offsetting projects in developing countries. Third, investment in greener technology can lead to productivity improvements that more than offset additional costs of environmental protection. This argument relies on the well-known Porter Hypothesis reviewed in section 4. Section 5 examines how green policy can increase competitiveness due to knowledge spillovers in the innovation process. The conclusions present policy recommendations for designing green growth policies that are likely to deliver competitive advantages in international markets.

2. HIGHER MARKET SHARES BY DIFFERENTIATING PRODUCTS BASED ON ENVIRONMENTAL QUALITY

2.1. SUPPLYING GREENER PRODUCTS AS A VERTICAL DIFFERENTIATION STRATEGY

Firms can reduce their negative impact on the environment by improving the environmental quality of their products throughout the products' life cycles. Firms can use less polluting inputs such as fewer pesticides or other harmful chemicals; increase their share of renewable sources of energy, such as wind and solar power; or adopt sustainable production procedures such as replanting forests after harvesting or using fishing practices that have less impact on ecosystems. They can also facilitate the recycling of their product and choose fewer or less polluting packaging materials (Haned et al. 2015). Firms are sometimes forced to do so when governments set more stringent regulatory standards, but in many cases firms go beyond minimal or mandatory standards on environmental quality.

Supplying greener products often entails additional costs for the producer. By going beyond mandatory standards and thus increasing their costs, companies put themselves at a disadvantage compared to competitors. Yet they might be able to recover this extra production cost through revenue if consumers agree to pay more for environmental quality. Supplying greener quality products can be viewed as a vertical differentiation strategy. By differentiating their products from those of competitors, firms move away from head-on comparison with many similar, or seemingly identical, products. That differentiation may only be the environmental intensity of their production methods. That approach takes advantage of the market power of a niche of consumers who are willing to pay more for greener products. Ultimately, the price premium on greener products can offset their higher production costs. Such a successful vertical differentiation strategy requires that consumers are able to identify products with higher environmental quality, ideally through eco-labels.

2.2. LABELLING AND CERTIFICATION

Firms can signal the higher environmental quality of their products through certification and labelling. Examples include the Forest Stewardship Council certificate for wood produced from sustainably managed forests and the Marine Stewardship Council certificate for seafood harvested using sustainable fishing practices. Organic food labels issued by the U.S. Department of Agriculture or by the European Commission are presently one of the most popular ways to differentiate products in the food industry. This does matter, since the similitude of many agricultural products means that label differentiation is often the only way to secure a competitive advantage. Organic food labels are well known by consumers and often supported by public authorities. This system can incur higher costs through mandatory certification procedures and lower yields for producers at least in the short run, as it restricts the use of many inputs, such as pesticides, antibiotics, or some fertilisers.[7]

Fair trade labels also have a green component insofar as they favour less intensive agricultural practices and organic standards. Environmental criteria in fair trade production include the banning of certain harmful chemicals, reduction of the use of pesticides, and promotion of natural biological methods to preserve soil and biodiversity such as crop rotation as well as a preference for less intensive small scale farming. Evidence shows that consumers are paying higher prices for labelled fair trade and organic products. For instance, in a survey of coffee producers in Central America and Mexico, Méndez et al. (2010) found a significant positive correlation between average sales prices for coffee for both fair trade and organic labels. A study of 228 Nicaraguan coffee producers evaluated an average price of US$ 0.84 per pound[8] for fair trade coffee, US$ 0.63 for organic coffee and US$ 0.41 for conventional coffee during the 2000–2001 coffee price crisis (Bacon 2005; Dragusanu et al. 2014). Hence, organic and fair trade certification can help producers offset higher production costs.

The final consumers are not the only ones to value the environmental attributes of products. Private companies often take steps to green their supply chain. For instance, production plants involved in the ISO 14001 environmental management systems certification procedure commit to using environmental performance criteria for selecting their suppliers.[9] Governments increasingly support products and suppliers with better environmental performance through green public procurement standards and policies. The U.S. Federal Acquisition Regulations provide detailed rules governing procurement by all federal agencies. For instance, these rules specify that the U.S. Environmental Protection Agency has to prepare guidelines on the availability, sources, and potential uses of recovered materials and associated products, including solid waste management services. These guidelines require federal agencies themselves to develop and implement affirmative procurement programmes for Environmental Protection Agency designated products (Kunzik 2003).

2.3. CREDIBLE LABELLING AND CERTIFICATION: A ROLE FOR GREEN POLICY

For the vertical differentiation strategy to be successful, the eco-label should convey credible and transparent information to consumers. Credibility requires that consumers trust what a label means in terms of environmental protection. The criteria for labelling and its implementation should be advertised in an understandable way for non-experts. Procedures for certification should be immune to corruption and manipulation by companies that would like to greenwash their products by obtaining a green logo without paying the cost of environmental protection. The label itself should be legible and easily identifiable for consumers. Public policy can help with that matter in several respects. Public administrations can facilitate the definition and dissemination of labelling criteria, support certification by agencies and NGOs, ensure the traceability of products along the supply chain, and simplify and harmonise the framing of labels to consumers. At the country level, public authorities should make labelling for international markets both feasible at a reasonable cost, and credible. Relying on the most respected and internationally known labels

7 For instance, Ramesh and others (2010) found that in India organic farming reduced yields by 9.2 per cent on average in the sample of certified farms they surveyed. The figures dropped by 20 per cent for rice and wheat and was up to 25 per cent lower than conventional farming for cotton.

8 Net of costs paid to the cooperative for transport, processing, certification, debt service, and export.

9 In a sample of 4,000 facilities in seven OECD countries, Johnstone and Lebonne (2007) found that 43 per cent assess their suppliers' environmental performance.

has many advantages. By facilitating the adoption of internationally recognised labels for green and sustainable products, public administrations can facilitate exports of eco-certified products to international markets where the labels are valued, especially higher income regions such as the EU. That can also help attract foreign investment in firms that produce eco-labelled products. Furthermore, supporting internationally recognised labels is an important criterion in the evaluation of the WTO consistency of government-supported standards under WTO law (Cosbey 2017, this volume).

3. SELLING AND ADOPTING GREEN TECHNOLOGIES

3.1. ENVIRONMENTAL POLICY TRIGGERS THE DEMAND FOR GREEN TECHNOLOGIES

Environmental regulations can also boost economic growth and economic activity for some sectors by spurring demand: solving environmental problems has become a business opportunity for companies supplying pollution-control technologies. For instance, the implementation of more stringent air quality standards in Europe and the US increased the demand for scrubbers to filter SO_2 and NOx emissions from coal power plants. It also fostered innovation in scrubber and coal combustion as more patents were issued following the application of the regulation (Popp 2006). Government intervention for environmental protection can therefore boost the growth of eco-industries, supplying technologies that mitigate or clean-up pollution.

Besides command-and-control regulation, such as more stringent standards, governments may also decide to apply market-based, or economic instruments. Instead of prescribing a certain environmental standard to be achieved or technology to be used, market-based instruments incentivise the adoption of clean technology or demand for pollution-control technologies. Subsidies are one popular economic policy measure often issued by governments as a way to offset additional cost of higher environmental standards for companies. They may therefore be used by governments to incentivise firms to adopt environmentally sound technologies that are cleaner but more costly. This can provide business opportunities for sectors and technologies that may not be competitive in the current economic environment or their current state of technological development.

Perhaps the most famous example of subsidies employed to advance environmental objectives, among others, is the feed-in tariff for renewable energy sources implemented in more than 50 countries including many developing countries. By issuing a feed-in tariff, public authorities commit to purchase electricity produced from wind and solar power at a fixed price, well above the wholesale market price. Many States in the US have opted for renewable portfolio standard programmes, which generally require a minimum proportion of electricity demand to be met by renewable sources. Those programmes are usually implemented on the basis of renewable energy certificates issued for verified renewable generators. Those entities exceeding their renewable energy obligations can earn money by selling certificates to other entities that fail to meet their obligations. Both types of support to renewables have been very successful. They have boosted the wind and solar power industries not only where they were implemented but also abroad. Massive investment in solar power in countries like Germany has not only given jobs to new companies involved in installing photovoltaic panels, but has also contributed to making China the largest solar photovoltaic cell producer in the world (Pegels 2017, this volume).

3.2. PHOTOVOLTAICS IN CHINA

From 2003 to 2009, the exponential growth of photovoltaic installations was concentrated in a few developed countries, primarily Germany, Spain, Japan and the US. Yet, during this period, the production of photovoltaic cells moved to emerging economies, notably China. Starting with a 1.6 per cent market share for cell and module assembly production in 2003, China became the world leader with a 35 per cent market share in 2007, just five years later, followed by the European Union, with 29 per cent market share (De La Tour et al. 2011). This shift of leadership from Europe to China has triggered much criticism in Europe's policy debate as feed-in tariffs were supposed to give first mover advantages to European companies in the wind and solar power industries. They did indeed promote activities that were not exposed to international competition, such as photovoltaic installation. However, China took advantage of low-cost labour and relatively cheap energy to set up cell production and module assembly lines without much prior experience in manufacturing cells. According to

De La Tour et al. (2011), China managed to obtain the technology through three channels. Importantly, China gained access to technology through purchasing the manufacturing equipment in a competitive market. Furthermore, they obtained the required skills and knowledge by way of hiring highly skilled Chinese executives trained abroad in universities or in the photovoltaic industry. China attracted foreign direct investment under a policy that obliged foreign investors to accept joint ownership. Such joint ventures are likely to induce more knowledge spillovers between the foreign investor and the local firm. From a country on the receiving end of technological transfers, China has evolved into a major producer in the photovoltaic solar industry.

3.3. CLEAN DEVELOPMENT MECHANISM AND CARBON OFFSET

Companies in developing countries have benefited from another policy involving transfers from developed countries: the Clean Development Mechanism (CDM) part of the Kyoto Protocol. This policy allows greenhouse gas emitters that are subject to emission reduction obligations to offset their own emissions by investing in emission-reducing projects in less developed economies. The aim is to take advantage of cheaper mitigation opportunities in developing countries, thus making climate change mitigation more cost-effective. The CDM can be used by companies, such as electricity producers or cement and glass manufacturers, involved in the European Union Emission Trading Scheme to obtain new allowances. It has been a substantial stimulant: during the 2002 to 2008 second phase, around 1 billion tonnes of CO_2 credits were bought in the Trading Scheme (European Commission 2017). More generally, many firms meet corporate social responsibility obligations by offsetting their own carbon emissions through carbon credits granted by the CDM.

The CDM creates carbon credits based on projects certified by the UN Framework Convention on Climate Change provided that an emission reduction is 'additional' to any that would have occurred in the most plausible alternative scenario to the implementation of the CDM project, or the business-as-usual scenario. The additionality criterion has been criticised for creating perverse incentives for developing countries, as it rewards the absence of climate mitigation policies. Projects must also be accredited by the host government, based on sustainable development criteria (Olsen and Fenhann 2008). One drawback of the CDM is that projects have been concentrated in only a few emerging economy countries—mainly China, India and Brazil—for only a few specific technologies. Overall, the CDM has nevertheless been very successful in bringing foreign direct investment into developing countries. It has turned into a lively market with 180 transactions involving US$ 2.5 billion in total in 2005 alone and up to US$ 6.5 billion more in 2008 (Lecoq and Ambrosi 2007; Kossoy and Ambrosi 2010).

3.4. GAINING COMPETITIVE ADVANTAGE BY ISSUING CARBON CREDITS

The projects financed by the CDM are diverse. Carbon credits can come from increasing the energy efficiency of buildings, or recovering biogas from agriculture and landfills, for example. Worldwide, a large share of CDM projects concerns electricity production through investments in renewable sources of energy such as hydro, wind, solar or biomass.

The economic gains that host countries derive from CDM projects extend beyond the company that implements a project for carbon credits. These gains sometimes spread to the supply chain of green technologies, fostering production in developing countries. For instance, most wind power projects implemented in India use equipment produced by local manufacturers, mainly Suzlon and Enercon India (Dechezleprêtre et al. 2009). Furthermore, many firms have used CDM projects as collateral to obtain upfront financing from financial partners. For instance, Lecocq and Ambrosi (2007) report the case of pig-iron producers in Brazil who obtained loans from a Dutch bank by transferring the carbon credits gain from replacing coal with lower GHG-emitting charcoal. Future credits are valuable collateral because they are paid in strong currencies—US dollars, euros or yen—by investors with high credit ratings.

Local companies have benefited from another key component of many CDM projects: technology transfers. In the sample of 3296 CDM projects examined by Schmid (2012), 36 per cent of them claimed to have a technological transfer dimension, accounting for 59 per cent of the total emission reduction. Haites et al. (2006) found a rate of technical transfers of the same magnitude in a sample of 860 CDM projects: one-third involved technology transfers and accounted for two-thirds of the annual emission reductions. In a closer look at CDM projects, Dechezleprêtre et al. (2008) distinguish between two types of technology transfer: knowledge transfer and equipment transfer. Knowledge transfer takes place when a local project benefits through the transfer of knowledge, information, technique or technical assistance from a foreign partner. Equipment transfer describes the import of devices such as wind turbines. In their sample of 644 CDM projects, the researchers found that 43 per cent of the projects involved technology transfers: 9 per cent consisted of only equipment transfer, 15 per cent included only knowledge transfer, and the remaining 19 per cent involved both equipment and knowledge transfer.

Dechezleprêtre's team investigated the determinants of technology transfers among CDM projects. Unsurprisingly, the size of the project and the openness to trade for the host country positively influence the probability of technology transfers. According to Schmid (2012), higher tariffs on environmental goods and services impede the likelihood of technological transfer in CDM projects. Reducing tariffs on those environmental products might make technological transfer easier. One key ingredient that might matter at the country level seems to be its technological absorptive capability. Technological absorptive capability refers to a country's ability to conduct research and to understand, implement, and adapt imported technologies (Popp 2011). It has to do with the workforce's technological literacy and skills, which are influenced by many factors that are controlled by public authorities, such as education and infrastructure. Overall, empirical studies have found no effect or an ambiguous role of technological absorptive capability on technological transfer (Dechezleprêtre et al. 2008; Schmid 2012; Murphy et al. 2013; Gandenberger et al. 2015). According to Dechezleprêtre's 2008 study, technological absorptive capability[10] has a positive influence on technology transfers in the energy sector and the chemical industry, but a strong negative effect in agriculture. According to the authors, the contrast seems to reflect an antagonistic effect that such capability has on international technology transfers. On the one hand, it facilitates transfer when firms in the host country have skills to adopt a new technology. On the other hand, it increases the likelihood that technology is already available locally, and therefore reduces the need for international transfers. The former effect holds in the energy sector and the chemical industry where more newly developed technologies and advanced techniques are involved, while the latter effect seems predominant in agriculture where local conditions influence the technological needs.

3.5. GREEN GROWTH BY ATTRACTING INVESTMENT IN CARBON OFFSETTING

Given the amount of money available through carbon credits, it might come as a surprise that most of the projects ended up in three countries: China, India and Brazil, which together accounted for nearly 80 per cent of the credits in 2006 (Lecoq and Ambrosi 2007). Most African countries were left out. Partially, this can be explained by the administrative costs of accreditation. Under the Kyoto Protocol, countries have to set up designated national authorities to participate in the CDM. The designated national authorities have to support projects by signing a letter of approval to issue carbon credits (Olsen and Fenhann 2008). While this process is meant to respect countries' sovereignty, it also means that no international standard for accreditation exists: countries have established their own distinct procedures and criteria. Therefore, it is easier for companies to focus on a few technologies in a small number of countries.

Governments can take action to attract CDM projects—and more generally attract investment for carbon offsetting—by making accreditation easier. Procedures could be standardised to help alleviate the administrative cost of setting up a CDM project (Schmid 2012). Governments can also design accreditation procedures to maximise the economic benefits from carbon offsetting investment. For instance, they can include technological transfers as a criterion for accreditation. As Popp (2011) showed, this has been the case in South Korea, which requires that "environmentally sound technologies and know-how shall be transferred" through CDM projects in Korea. As a result, 88 per cent of the emissions reductions from CDM projects in South Korea come from projects that involve technology transfer. Similarly, Chinese guidelines for CDM project approval stipulate that "CDM project activities should promote the transfer of environmentally sound technology to China" (Haites et al. 2006). As discussed above, depending on the sector, technology transfers can be made more likely through a targeted increase in a country's absorptive capacity (Dechezleprêtre et al. 2008; Popp 2011), as well as openness to trade, and thus support a country's economic development and growth.

10 While this paper uses the term 'technology absorptive capacity', Dechezleprêtre's study employs the term 'technological capabilities', which is constructed following an index of technological capabilities developed by Archibugi and Coco (2004). The index accounts for the following factors: the creation of technology (number of patents and number of scientific articles), the technological infrastructures (Internet penetration, telephone penetration and electricity consumption) and the development of human skills (percentage of tertiary science and engineering enrolment, mean years of schooling and literacy rate).

4. INCREASE A FIRM'S PRODUCTIVITY: THE PORTER HYPOTHESIS

4.1. THE PORTER HYPOTHESIS

More than 20 years ago, Michael Porter suggested that pollution was generally associated with a waste of resources, or with lost energy potential: "Pollution is a manifestation of economic waste and involves unnecessary or incomplete utilisation of resources... Reducing pollution is often coincident with improving productivity with which resources are used" (Porter and van der Linde 1995). Based on this reasoning, Porter argues "properly designed environmental regulations can trigger innovation that may partially or more than fully offset the costs of complying with them." This has come to be known as the Porter Hypothesis. In other words, it is possible to reduce pollution emissions and production costs at the same time, resulting in 'win-win' situations.

The Porter Hypothesis is controversial: First, the evidence initially provided to support it is based on a small number of company case studies, in which firms were able to reduce both their pollution emissions and their production costs. As such, it can hardly be transferred to the entirety of firms. Second, economic theory would suggest that, if there are opportunities to reduce costs and inefficiencies, companies should identify them by themselves without the need for government intervention (Palmer et al. 1995). However, many studies have proposed analytical justifications for the Porter Hypothesis. It could be that the interests of companies and their managers are not aligned, perhaps due to risk aversion, time-inconsistency, asymmetric information, or other circumstances. Regulations force firms to adopt innovations that are profitable for the firm but not for its managers. As Ambec and Barla (2006) argue, the Porter Hypothesis can be valid if a market failure exists in addition to the environmental externality. Examples include knowledge spillovers or market power. For instance, Simpson and Bradford (1996) investigate the impact on environmental regulation in a model with firms competing on international markets. They show that more stringent environmental regulation commits a domestic firm to an aggressive cost-reducing programme, thereby creating a first mover advantage.

4.2. EMPIRICAL EVIDENCE OF THE PORTER HYPOTHESIS

On the empirical side, Jaffe and Palmer (1997) present three distinct variants of the Porter Hypothesis. In their framework, the 'weak' version of the hypothesis is that environmental regulation will stimulate certain kinds of environmental innovations, although this does not mean that the innovation is socially beneficial. The 'narrow' version of the hypothesis asserts that flexible, market-based environmental policy instruments, such as pollution charges or tradable permits, give firms a greater incentive to innovate than do prescriptive regulations such as technology-based standards. Finally, the 'strong' version posits that properly designed regulation may induce innovation that more than compensates for the cost of compliance and improves the financial situation of the firm. Many researchers have tested the different versions of the Porter Hypothesis empirically. Overall, the empirical literature provides evidence for the weak version but not for the strong one. Most studies find a positive although sometimes muted relationship between, on the one hand, more stringent environmental policies and innovation measured by investment in research and development and, on the other, new technologies or successful patent applications. However, some studies find that the impact of environmental regulations on productivity or business performance turns out to be negative in general (Lanoie et al. 2011; Ambec et al. 2013).

Other empirical investigations suggest that the impact of regulation on productivity may depend on its stringency: For instance, Berman and Bui (2001) found that refineries located close to Los Angeles are significantly more productive than other US refineries, despite the more stringent air quality regulation in the Los Angeles area. Similarly, Alpay et al. (2002) report that the productivity of the Mexican food-processing industry is increasing with the pressure of environmental regulation, which leads them to conclude that more stringent regulations can positively affect productivity. It seems that, albeit the scientific evidence of a win-win situation, as Porter suggests, is mixed, more stringent environmental regulation can be good for business by fostering innovation, which provides firms with competitive advantage. The open question for policymakers is how to design policies to obtain a causal chain as proposed in the Porter Hypothesis.

4.3. PUBLIC POLICIES FOR PROFITABLE GREEN INNOVATIONS

Porter favours stringent but flexible economic instruments such as pollution charges or tradable emission permits. These economic instruments are more likely to enhance innovation than command-and-control instruments, such as technological standards, as they give more freedom to firms with regards to the technology used to abate pollution. In contrast, by imposing a given technology or certain inputs, a technological standard provides fewer incentives to innovate. Similarly, emission or performance standards do not encourage firms to go beyond the standards set. On the other hand, environmental policy instruments such as pollution charges can provide an incentive for firms to emit less as they can save money by reducing emissions further. Similarly, in the presence of an emission permits trading system, firms can save money by purchasing fewer permits on the market or even sell their own emission endowments by cutting emissions beyond their own emission rights.

The use of economic instruments appears to be a necessary condition for the Porter Hypothesis to hold. This is known as the narrow Porter Hypothesis. Economic instruments may support compliance with environmental regulation by rewarding champions and punishing laggards within the industry. One way to do so, is through a 'feebate', a differentiated tax and subsidy scheme around an emission target: Firms are taxed for pollution emissions above the target, and subsidised for emission units below it. Examples include the so-called 'eco-bonus-malus' scheme implemented in France for vehicle CO_2 emissions (d'Haultfoeuille et al. 2014). Cars that emit more than the standard are taxed, while those emitting less are subsidised. To reduce potential negative effects on profits within an industry, pollution charges can be earmarked within the taxed industry. The money collected can be redistributed directly to firms, depending on size, measured by output or work force. It could also be used to subsidise environmental research and development or the adoption of cleaner technologies.

Other environmental policy mechanisms, like cap-and-trade schemes may be difficult to establish politically. One way to improve political feasibility of such a scheme can be to give away a number of permits for free to an industry, at least during the initial distribution phase. Under this approach, firms will still have incentives to invest in pollution abatement technologies as long as they can make money by selling additional permits. Later on, fewer permits should be granted for free and more sold by auction, to ensure entry of new players into the industry.

Other policy instruments can be effective in greening firms. Voluntary approaches can be a substitute for mandatory environmental constraints in countries with weak institutions (Never and Kemp 2017, this volume). Examples include information disclosure programmes or programmes to encourage ISO 14001 certification through training and advertising the benefits of certification. Empirical evidence supports this. For instance, Powers et al. (2011) found that India's Green Rating Programme caused large pulp and paper plants with the worst environmental performance in their study to reduce emissions of certain pollutants by 9 to 19 per cent. In the same vein, Garcia et al. (2007) estimated that Indonesia's PROPER programme reduced firms' emissions by one-third.

5. INCREASE A SECTOR'S PRODUCTIVITY THROUGH KNOWLEDGE SPILLOVERS

5.1. KNOWLEDGE SPILLOVERS AS A MARKET FAILURE

Green policies can create demand and may therefore provide incentives to invest in research and development in this sector and may therefore provide incentives to invest in research and development in this sector, fostering innovation in environmentally sound technologies. These may generate positive externalities among firms in the research and development process. As knowledge is by nature a public good, and new technologies become public knowledge when transferred to production processes, firms will often not get the full return on their research and development investments: Some, if not all, of the knowledge embodied in the invention also becomes available to competitors who can fully or partly copy or improve the new technology. These knowledge spillovers benefit the economy, and society as a whole, whenever new technologies are developed; yet they discourage individual firms from investing in new technologies. As a result, market forces underprovide research and development investment. Public policies that foster investment in environmentally sound technologies should mitigate this market failure for the benefit of all and assure that an optimal level of research and development investment is provided, including for innovative firms.

5.2. KNOWLEDGE SPILLOVERS FOSTERING GREEN INNOVATION

Recent estimates suggest that knowledge spillovers do also have significant positive effects on green innovation. Dechezleprêtre et al. (2014) analyse knowledge spillovers in clean and dirty technologies, based on patent citations. This information is part of the state-of-art patent applications: Innovators applying for a patent are required to cite all previous innovations on which the new innovation is based. A citation indicates that the knowledge contained in the document has been useful to develop the innovation. For this reason, patent citation can be seen as a measure of knowledge spillovers. The 2014 study by Dechezleprêtre et al. covers four technological fields: energy production, automobiles, fuel and lighting. Clean patents receive an average of 43 per cent more citations than dirty patents, and are cited by more prominent patents. These results suggest that public support to research and development would be more effective in boosting innovation and growth if they targeted green technologies.

The positive effect of policy supporting research and development is likely to hold primarily for developed countries where most of the innovation occurs, including for green technologies. For instance, Lanjouw and Mody (1996) found that the US, Japan and Germany accounted for two-thirds of climate mitigative or adaptive innovation. Yet emerging economies increasingly produce a significant share of green innovations. In the sample they analysed, Dechezleprêtre et al. (2011) found that 18.5 per cent of the climate-oriented innovations patented from 2000 to 2005 originated in China, South Korea, Russia or Brazil. It is likely that emerging economy countries will catch-up on green innovation, triggered by domestic green policies, by the demand for green technologies from developed countries and by investment in carbon offsetting.

Another important component of the geography of innovation is knowledge dissemination. Dechezleprêtre et al. (2011) estimated the export of climate mitigative inventions by country. They found that emerging economy countries tend to export less than developed countries: around 7 per cent for China or for Brazil, as compared to 42 per cent for the United States or 56 per cent for Germany. This suggests two particularities of the innovation process in emerging economies. First, emerging economy countries tend to specialise in adapting green technologies to local conditions. Second, spillovers are likely to be greater within the country itself than abroad, which is an argument for increasing support to research and development in emerging economy countries, as most of the gains of innovation will benefit local constituents.

5.3. POLICIES FOR GREEN INNOVATION

As we have seen in section 4, there is now ample evidence that environmental regulation can stimulate innovation in green technologies. Moreover, knowledge spillovers can lead to productivity-enhancing innovation reinforcing the positive effect described by the Porter Hypothesis. Public policies that increase the demand for green technologies do not only reduce pollution and the use of natural resources, they also foster innovation and therefore growth.

Governments can promote innovation in green technologies in several ways. First, firms should be rewarded for investing in research and development, which means protecting their inventions with effective patents, thus mitigating the problem of market failure as outlined in 5.1. Public authorities can support green innovations by granting patents more easily, reducing transaction costs for submitting new patents, and enforcing the property rights of patents. This means facilitating patent monitoring and litigation through the judicial system. Another measure can also be to facilitate technology transfers through licensing agreements. Also, firms can be rewarded for investment in research and development by the provision of subsidies or tax cuts.

Second, since technological absorptive capacity is seen by some authors as a determinant of a country's ability to innovate, governments should invest in education, technological training and knowledge dissemination infrastructure, including internet access. In emerging economies, these factors can help foster innovation in green technologies that are best suited to local conditions. In less developed countries, this can facilitate the transfer of green but complex technologies in some sectors such as the energy sector for wind and solar power. As Vidican Auktor (2017, this volume) shows in her case study on renewable energy in Morocco, the country provides significant opportunities for the localisation of certain products and services and the creation of green jobs. Moreover, such investments may be able to further attract CDM and carbon offset projects.

6. SUMMARY AND CONCLUSION FOR GREEN GROWTH

Being environmentally sound does not need to be detrimental to competiveness. A firm can deploy several strategies to reduce its negative effect on the environment, while at the same time securing a competitive advantage in international markets. It can invest in environmental research and development, adopt cleaner technologies, supply environmentally sound technologies and enhance its product's environmental quality continually. Even if those strategies turn out to be costly, they can be profitable. Investment in cleaner technologies can lead to productivity improvements in the long run, which will then spread through knowledge spillovers. Carbon finance, such as investment in CDM and other carbon offsetting projects, now drives demand. Renewable energy mandates contribute to this demand, through measures like feed-in tariffs and renewable portfolio standards. In response, firms that specialise in producing climate-oriented technologies are expanding, particularly in emerging economies, through the installation of solar photovoltaic panels, wind turbines and other renewable energy sources. Finally, the growth of organic farming and fair trade has created new opportunities in agriculture and the food industry in many developing countries.

Many public policies can help to secure a competitive advantage with green business strategies. First, environmental policy instruments targeted at fostering green innovation should be flexible. This means implementing economic instruments such as refunded emission taxes or tradable allowances rather than prescribing technologies through specific regulation. Second, industrial policy should make patenting and technological transfer easier and more effective. It should also favour public support for environmental innovation to mitigate underinvestment due to knowledge spillovers. Third, technological absorption capacity should be improved by investing in education, technological training and infrastructures, such as communication, transportation and energy. Fourth, governments should work with non-government organizations and international organizations to facilitate environmental labelling with transparent criteria and a reliable traceability of products throughout the supply chain.

To conclude, three issues deserve further mentioning: First, public policies that have been successful in the past in bringing green growth might not be effective in the future. In the last years, the generous support for wind and solar power through subsidies has been cut in many countries in Europe, with some countries like Germany now switching from a feed-in tariff system that had long been considered successful to a competitive bidding process. For a variety of reasons, CDM projects have become less attractive in recent years. The volume of carbon-offsetting projects has fallen since 2012. In 2015, the market experienced an excess supply of projects. The average price per ton of CO_2 for all projects was US$ 3.3 in 2015, with a record US$ 0.1 for the lowest valued projects (Hamrick and Goldstein 2016). However, the 2015 Paris Agreement might reverse this trend. In Article 6, the Agreement launches a new mechanism that aims at financing carbon-offsetting projects in developing countries through Internationally Transferred Mitigation Outcomes. Importantly, policy instruments need to be well suited to the particular context in which they are employed and therefore will require readjustments over time.

Second, policies implemented for enhancing profitable green growth should suit a country's respective level of development. Less developed countries should prioritise improving their technological absorptive capacity, simplifying and standardising the accreditation process for carbon offsetting projects and building up a reliable supply of green, certified products for export. Emerging economy countries can afford to subsidise investment in green technologies to support their own industry. They should also strengthen their intellectual property rights to attract technological knowledge from foreign investors and encourage its transfer.

Finally, it is worth mentioning that protecting natural resources and reducing pollution enhance societal well-being through several channels that can be indirectly beneficial to firms. Economic activities rely on ecosystem services provided by forests, soils, rivers, lakes and oceans. Workers are in better health and thus more productive if they have access to clean water and air. All those indirect effects should be included in an accurate cost-benefit analysis of green policies.

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CHAPTER 4

ENHANCING JOB CREATION THROUGH GREEN TRANSFORMATION

Michela Esposito, Alexander Haider, Daniel Samaan, Willi Semmler

1. INTRODUCTION

Over the last decades it has become clear that economic growth has to be environmentally sustainable and socially inclusive. A production mode is needed that is less reliant on fossil fuels and uses natural resources more efficiently (OECD 2014; UNEP 2011). To this end, economies will have to go through a process of structural transformation. This process can be induced and guided by green industrial policies. Such structural change towards an environmentally sustainable economy will have, and already has, considerable effects on labour markets and incomes (ILO 2011; ILO and UNEP 2012). While green transformation poses challenges for certain polluting sectors and related jobs, it also creates opportunities for new jobs in other industries and may open the way for more and better jobs in the future.

This chapter identifies and discusses opportunities and challenges for labour markets and provides examples of policies and practices that can help achieve an inclusive and employment-intensive green transition. Section 2 provides a systematic overview of how green transformations may affect the quantity and quality of employment. In section 3 we undertake an attempt to define green jobs. Section 4 presents empirical evidence on employment trends in those labour market segments that can be attributed relatively well to green sectors. Section 5 introduces an overview of labour market and social policies that can facilitate a green transition from a social point of view. The conclusion summarizes the key findings of this chapter.

2. HOW GREEN TRANSFORMATIONS AFFECT EMPLOYMENT

Industrial policies are commonly understood as government policies that attempt to strategically strengthen the development and growth of certain economic activities and that very often, but not necessarily, concern parts of the manufacturing sector. If industrial policies achieve their goals, they lead to a structural transformation of the economy, or accelerate or decelerate an already ongoing transformation. During this process, inevitably, new jobs and occupations emerge while others disappear. The net employment effect of such a transformation is the difference between new jobs created and old jobs lost.

Green industrial policies, specifically, target the improvement of environmental quality and contribute to environmental sustainability (Altenburg and Rodrik 2017, this volume). Most environmental policies contain features of industrial policies, as they provide incentives to accelerate the development of certain sectors, sub-sectors and technologies and to phase out others. As a result, sectors with strong effects on the environment, as well as workers and enterprises operating in these sectors, will be more affected than others. The first step in understanding the effects of green industrial policies on labour markets and incomes is to identify the sectors that strongly affect the environment. These include sectors with activities directly aimed at the preservation or restoration of the environment such as for recycling, renewable energy, or eco-tourism; sectors strongly relying on the utilisation of natural resources such as heavy industries or fisheries and sectors with heavy polluters such as fossil fuel-based energy production. These sectors will see the largest adjustments in employment, while effects in other parts of the economy may not be as intense.

Affected sectors will not necessarily be identical across countries. Improving or preserving environmental quality covers a whole range of potential issues, ranging from pollution of air and water, global climate change, ocean degradation, waste production, depletion of non-renewable resources, unsustainable use of renewable resources, loss of biodiversity, to degradation of soil (ILO and UNEP 2012; ILC 2013). As countries face different environmental challenges, the requirements of structural transformation vary, as do related employment challenges and outcomes. For example, greenhouse gas (GHG) emissions in Brazil arise largely from agriculture and forestry, whereas in Germany they mostly stem from electricity generation, manufacturing and the transport sector. The German energy sector has traditionally used more non-renewable resources such as coal, oil and gas than Brazil, which traditionally relied on hydropower; and per capita water consumption for agricultural purposes is much higher in Brazil than in Germany. These brief examples show that countries face very different challenges on their paths towards an environmentally sustainable future. Accordingly, workers and enterprises will be affected differently.

When trying to measure the employment effects, various dimensions need to be taken into account. On the one hand, there are jobs that are newly created in greener sectors, industries or enterprises as well as those that emerge due to spillover effects in non-green sectors. Spill-over jobs in other sectors may emerge through supply chains into green sectors as indirect jobs, through increased capacity of non-green sectors as improved competitiveness through higher resource productivity, or through additional consumer demand resulting from newly created incomes as induced effects. On the other hand, environmental policies may negatively affect labour absorption in polluting industries. For example, successful development of a competitive renewable energy sector would most likely reduce the number of jobs in the coal mining industry and along its supply chain. Estimating the overall impact of green industrial policies on the total number of jobs in the economy is therefore difficult and poses some methodological challenges.

While net employment effects of a transition are important and of high interest to policymakers, the gross effects—the total numbers of jobs created and lost in different segments of the economy—are also essential from an employment policy perspective. The shift of jobs across enterprises, industries, and sectors may entail adjustment costs for enterprises and workers. Additional government policies may become necessary to support or even trigger these transitions. Shifting employment patterns can also affect occupations, defined as a category of jobs with main tasks and duties that are characterized by a high degree of similarity, and therefore have ramifications for the development of skills and re-training as well as adjustments of the education system (ILO 2012).

Moreover, employment considerations should not only concern the number of jobs created or lost, but also their quality, including governance and coordination mechanisms. This comprises a whole range of themes relating to the world of work. The International Labour Organization (ILO) has developed a Decent Work Agenda that distinguishes four objectives that also address quality of employment (ILO 2017): promoting jobs by boosting investments, skills development, new job creation and sustainable livelihood; guaranteeing rights at work; extending social protection by ensuring equal and safe working conditions for men and women, ensuring a balance between working hours and rest and access to healthcare; and promoting social dialogue between employees and employers. The promotion of "sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all" has been included into Sustainable Development Goal 8 as part of the United Nations' 2030 Agenda for Sustainable Development that aims to achieve economic, social and environmental sustainability by 2030 (UN 2015).

Many aspects of the world of work are regulated by International Labour Standards issued by the ILO. The adherence to International Labour Standards can help improve employment outcomes. A green transformation is successful, from the perspective of green industrial policies and the ILO's Decent Work Agenda, if the transition leads to less environmental damage by the economy, for example lower total GHG emissions per unit of gross domestic product, and to better employment outcomes, in terms of more jobs, better job quality and better compliance with International Labour Standards.

3. DEFINING GREEN JOBS

There is no generally agreed definition of green jobs. One challenge lies in defining when a sector, and accordingly an employment or occupation in this sector, is green. Only a few economic sub-sectors, such as the production of wind turbines or solar panels, can be unambiguously classified as green industries. In most activities, boundaries between green and non-green are blurred. When an auto part is incorporated in an electric vehicle it may be considered a green product, but when the same part is assembled into a conventional car it would not be considered a green product. An additional difficulty results from the fact that technology evolves. An industry that is green today, in the sense that it has an above-average environmental performance, may fall behind international standards over time and would no longer be considered green.

Furthermore, it should be considered that a green product or service can be produced through an environmentally unsustainable production process such as a wind turbine built with inputs produced and transported in a CO_2 intensive way; and a green production process can produce a non-green product or service, such as production of petrol-powered cars with reduced water use. Hence, it is important to distinguish between environmental impacts of production processes and outputs.

The definition of green jobs used by ILO includes those in sectors that produce green goods and services as well as occupations in green processes that are environmentally favourable (ILO and UNEP 2012). In addition, the ILO green jobs definition includes the constraint that they must be decent jobs. The International Conference of Labour Statisticians (ICLS) proposed to consider criteria that define jobs that belong to the environmental sector as well as criteria that define decent jobs. The Conference proposal is meant to be consistent with the standards used in labour statistics, such as some sets of decent work indicators from the ILO, and with the standards in environmental statistics, such as the System of Environmental-Economic Accounting (SEEA), established by the United Nations (United Nations Statistics Division 2003; UN 2012). Based on the latter, the ICLS defines environmental activities as activities with the aim of eliminating or diminishing pollution and deterioration of the environment or of using natural resources more efficiently. These environmental activities can be the main activity of an economic unit or an auxiliary one, and can be carried out for sale or for own consumption. The US Bureau of Labour Statistics uses a similar definition. The European Commission's statistics agency, Eurostat, uses Environmental Goods and Services Sector (EGSS) categories (Eurostat 2009). According to its definition, EGSS categories are goods and services produced for two general purposes: environmental protection–preventing, reducing and eliminating pollution and any other degradation of the environment; and resource management–preserving and maintaining the stock of natural resources and hence safeguarding against depletion.

The definition of green jobs to be used will depend on its purpose. For example, to determine new skill requirements of new occupations and new jobs, a narrow definition of green jobs in environmentally related activities may be most helpful; while an analysis of the social dimensions of a green transition may require a broader focus on employment effects throughout the economy. No matter which definition is applied, green jobs are in any case only a subset of the overall employment effects that will arise during a green transition.

4. EMPLOYMENT EFFECTS OF GREEN TRANSFORMATIONS: WHAT DO WE KNOW?

Given the blurred boundaries between green and non-green products and processes as well as the heterogeneity of environmental challenges across countries, it is impossible to unambiguously quantify the overall employment impacts of green transformation. However, some estimates exist for parts of the green transformation. A few key studies have investigated the employment effects of green industries at national levels. Due to different definitions used, these are not comparable, but taken together they provide a fairly good overview of trends.

This review uses three types of information: First, there is evidence from OECD countries, including aggregate statistics on the Environmental Goods and Service Sector as well as publications that shed light on specific sub-sectors and on impacts of certain green policies on labour markets in these countries. Second, there is documentation from a selected number of developing countries showing the employment gains at initial stages of transformation as green industries emerge. It should be noted that none of these sources tracks job losses in polluting industries, spillover effects into non-green industries, or changing occupations and skills requirements. Third, there are some estimates of the carbon-intensity of economic activities, which allow us to assess which sectors are likely to experience the largest labour market changes.

4.1. EVIDENCE FROM OECD COUNTRIES

Employment estimates of the environmental sector have been conducted mostly within the EU. First attempts to estimate its size were undertaken by the OECD and EU (OECD and Eurostat 1999). Ecotec (2001) was one of the first studies to analyze the size of the sector within the EU for the period 1994 to 1999. Over 2 million full-time equivalent green jobs existed in the EU in 1999, with approximately 1.5 million jobs in pollution management and around 650,000 jobs in resource management. Employment growth rates in these activities were above economy-wide averages. The fraction of employment in the environmental sector over total paid employment was approximately 1.3 per cent.

As the number of EU countries expanded, the Ecotec report was updated by Ernst & Young in

2006, showing that total employment increased from 1.45 million jobs in the EU-15 of 1999 to 1.85 million in the EU-25 of 2004 in pollution management activities while resource management activities increased from 0.6 million in the EU-15 to 1.04 million jobs in the EU-25 over the same period (Ernst&Young 2006). A 2009 update analyzed green jobs through to EU-27, between 2000 and 2008 (Ecorys 2009) (Table 4.1).

Table 4.1: Employment estimates of green jobs in the European Union

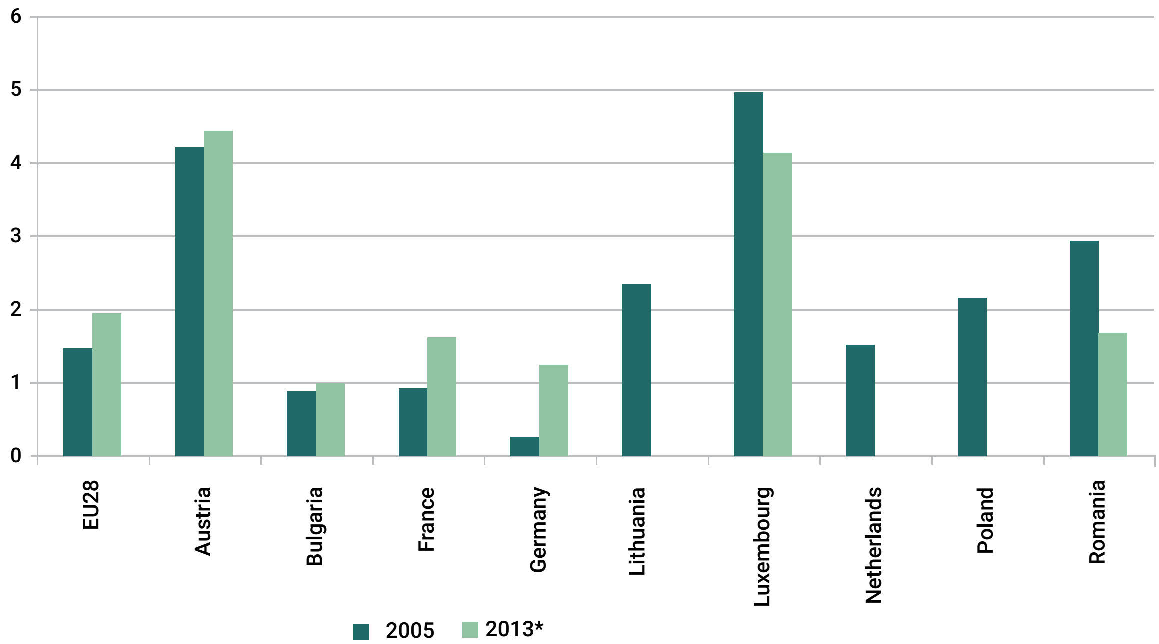
Activity	**Employment (2000)**	**Employment (2008)**	**Growth rate % Average annual**
Waste management	844,766	1,466,673	7.1
Water supply	417,763	703,758	6.7
Wastewater management	253,554	302,958	2.3
Recycled materials	229,286	512,337	10.6
Others	129,313	193,854	5.2
Renewable energy	49,756	167,283	16.4
Air pollution	22,600	19,067	-2.1
Biodiversity	39,667	49,196	2.7
Soil & Groundwater	14,882	18,412	2.7
Noise & Vibration	4,176	7,565	7.7
Total	**2,005,764**	**3,441,102**	**7.0**

Source: Ecorys (2009)

As the UN established the SEEA framework, the EU's EGSS concept evolved to complement it. Eurostat shows that across the EU the share of EGSS in total value added grew by more than 50 per cent between 2000 and 2012, while employment grew from 2.785 million to more than 4.1 million in full-time equivalents during the same period, which corresponds to an average annual growth rate of about 3 per cent. The majority of these new jobs were created in energy resource management, in particular the production of energy from renewable sources, the production of wind and solar power stations and equipment, and installations for heat and energy savings. Figure 4.1 shows the development of the EGSS in selected EU countries and the EU28 between 2005 and 2013. The growth rate of jobs has been mostly positive. According to Figure 4.2, the employment shares of the EGSS for the latest available year (2014) range from around 0.9 per cent of total employment in Ireland up to 4 per cent in Austria and Luxembourg.

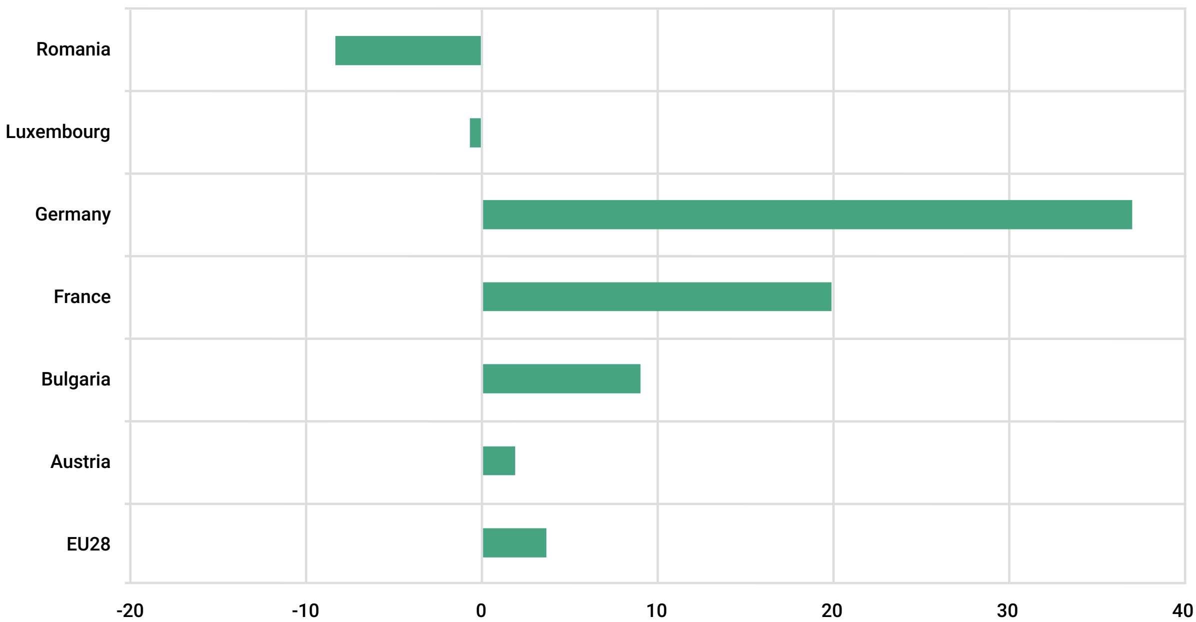
Figure 4.1: Employment in the environmental sector, 2005–2013

Panel A: Employment shares in EGSS in EU countries



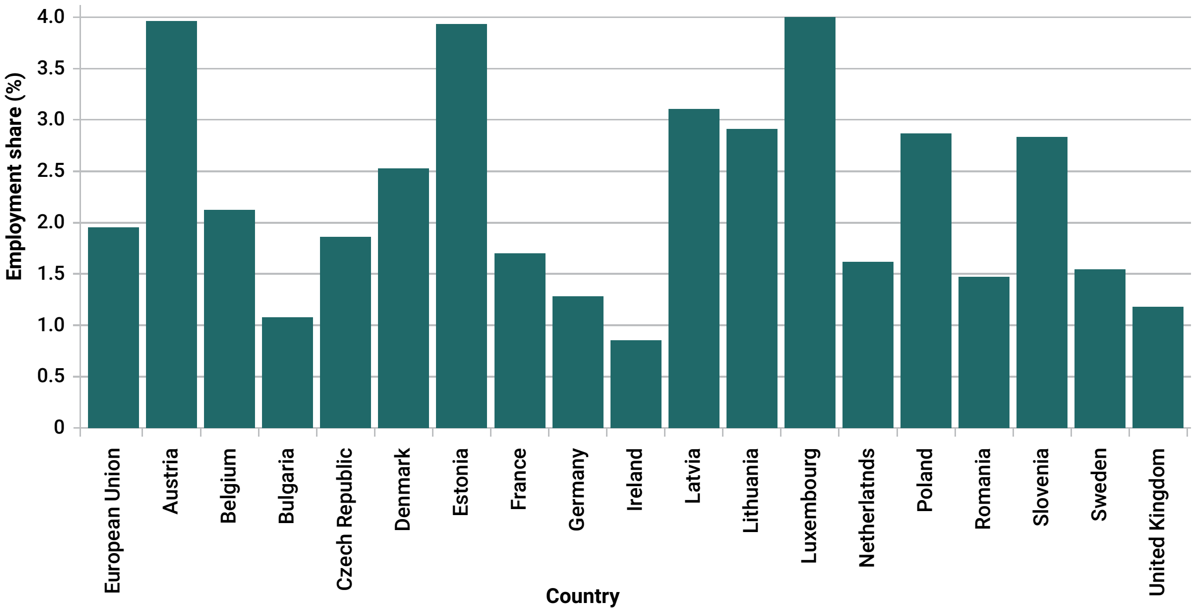
Note (*): For Austria, Germany, Luxembourg, Netherlands and Romania the shares are from 2012, for France and Lithuania, the shares are from 2011. For some countries the base year (2005) refers to 2007 or 2008. Thus, not comparable by definition.

Panel B: Annual employment growth in EGSS in EU countries, 2005–2013



Source: ILO Research department based on Eurostat.

Figure 4.2: Employment shares in EGSS in EU countries, 2014



Until the function was defunded in 2013, green job estimates were made in the United States by the Department of Commerce and by the Department of Labor's BLS using a case-by-case classification of green industries. The US Department of Commerce (2010) estimated the number of green jobs in the United States in the private sector in 2007 to be around 2.4 million, under a broad definition, which amounted to 2 per cent of total private sector employment in that year. BLS (2012) estimated that around 3.4 million jobs in the United States could be classified as green jobs in 2011 with around 2.5 million of those in the private sector. The BLS figures suggest that 2.3 per cent of private sector jobs, and 4.2 per cent of public sector jobs, can be classified as green jobs in the US, but none of these numbers consider the aspect of ILO's Decent Work. Given the most up-to-date estimates, the biggest share in US green private sector employment was in manufacturing, followed by construction and professional, scientific and technical services (BLS 2012).

For the United States, Pollin et al. (2008) estimate the projected employment effects of a proposed 10-year green recovery programme. It would consist of ten broad implementation steps, ranging from a cap-and-trade system to technology-specific programmes. The authors consider six green investment areas: retrofitting buildings, mass transit, smart grid, wind power, solar power and advanced bio-fuels. They estimate that 935,200 direct jobs would result, along with 586,000 indirect jobs and 496,000 induced jobs, by spending $100 billion in these investment areas. According to the projection, the green recovery programme would produce larger total employment effects and generate higher household incomes than investing in alternative scenarios such as the oil industry.

Morgenstern et al. (2002) also focus on the US, investigating the effects of environmental policies for four industries: pulp and paper mills, plastic manufacturers, petroleum refiners, and iron and steel mills sectors. On average, a US$ 1 million increase in environmental spending would produce 2 to 3 additional jobs across the four industries. Belova et al. (2013) revised those estimates by increasing the number of industries included in the analysis. For the same four industries, the authors find larger employment effects than Morgenstern et al. (2002). For the other six industries, results were positive and significant only for the rolling and drawing industry. In particular, each additional US$ 1 million of environmental expenditure would produce 22 to 23 additional jobs in rolling and drawing. Finally, the authors conclude that for 6 out of 10 industries, the model indicates 10 to 30 additional employees hired for US$ 1 million spent in abatement expenditures (Belova et al. 2013).

Kato et al. (2012) analyze the short-term effects of an environmental tax on structural change for a set of nine high-income countries: Germany, Australia, France, Hungary, Japan, Korea, Sweden, UK and the US. They distinguish between high and low intensities of carbon-consuming sectors and evaluate three different policy options.

The first option is a carbon tax levied on goods produced by highly carbon-intensive sectors and a subsidy paid on goods produced by low carbon-intensive sectors. The overall employment effect is estimated to be positive at around 0.5 per cent. Secondly, they examine the effects of a carbon tax levied on goods produced by high carbon-intensive sectors, without any subsidy in return. In this case, the carbon tax would produce a decrease in employment of roughly 0.4 per cent. The last policy option consists of a carbon tax levied on highly carbon-intensive sectors and a revenue-neutral wage subsidy paid to both sectors. This policy would produce the greatest net gains in terms of employment and output.

UNEP (2008) uses a literature survey to estimate the employment effects of green transformation and, in particular, energy efficiency improvements in six economic sectors: renewable energy, buildings, food and agriculture, basic industry and recycling, transportation and forestry. In the renewable energy sector, the net employment effect produced by green transformation ranges from 1.4 to 2.5 million jobs by 2020 in Europe, while estimates for the US vary considerably. For instance, a study conducted by the American Solar Energy Society estimates that by 2030 the US will have created 1.3 million direct and 7.9 million indirect jobs in renewable energies under a business-as-usual scenario in renewable energy (UNEP 2008). According to IRENA (2017), renewable energy employment was 1,163,000 in the European Union and 777,000 in the United States in 2016. In the residential building sector, Wade, Wiltshire and Scrase (2000) found that energy-efficient investment programmes would produce positive effects in nine European countries. In particular, for every EUR 1 million invested in energy-efficiency programmes, 11.3 to 13.5 full-time equivalent direct jobs would be created.

4.2. DOCUMENTATION FROM DEVELOPING COUNTRIES

For developing countries, the evidence is even more patchy. With regard to renewable energy excluding large hydropower, IRENA (2017) shows major employment effects for China at 3,643,000 jobs, Brazil at 876,000 jobs, India with 385,000 jobs and Bangladesh with 162,000 jobs in 2016. A general overview of a number of sources can provide more anecdotal evidence from a number of specific case studies in developing countries, describing both what already exists and projections for future green jobs.

A number of studies document the evolution and effects of ethanol production from sugarcane in Brazil (Smeets et al. 2006; Goldemberg et al. 2008; Herreras Martinez et al. 2013; Motta Veiga and Polónia Rios 2017, in this volume). Goldemberg et al. (2008) estimate that for 300 million tons of sugarcane produced, 700,000 direct jobs are created, directly and mainly in agriculture, and indirectly through supply chains for equipment, chemical supplies, production and maintenance. The number of jobs per unit of energy produced also exceeds the number of jobs required by the oil industry for the same output. Concerning wages, the authors report that workers in the sugarcane industries in Sao Paulo State receive around 80 per cent higher wages than workers in the production of other agricultural crops. Sugarcane wages were even higher than 50 per cent of those in services and 40 per cent of those in industry. Wages in the less-developed Northeast Region remain lower than in Sao Paulo State, although wages have been rising there, too.

Employment in this sector is highly formalized: In sugarcane production, 72.9 per cent of the jobs are formal, compared to only 40 per cent of other rural jobs in Brazil. In Sao Paulo State, formal employment in sugarcane production reached 93.8 per cent by 2005. In the Northeast Region the formal to informal employment ratio amounts to only 60.8 per cent, yet this is still higher than the average figure for agriculture. Since the early 2000s, the number of jobs has been decreasing in sugarcane and ethanol production due to mechanisation (Smeets et al. 2006). As Herreras Martínez et al. (2013) point out, mechanisation has been deliberately promoted by policy decisions to decrease soil degradation and to reduce air pollution due to sugarcane field burning used in manual harvesting (Motta Veiga and Polónia Rios 2017, in this volume). Still, the sector offers a considerable number of decent jobs in agriculture. At the same time, skill levels have been increasing in the sugarcane industry since the early 2000s, while additional investment for job creation is relatively low in ethanol compared to the chemical and petrochemical industry (Smeets et al. 2006). Herreras Martínez et al. (2013) forecast future developments in biofuel production in Brazil's Northeast Region using input-output models. Different scenarios are simulated and increases in productivity and employment, ranging from 12,500 up to 160,000 jobs until 2020, are estimated.

ILO and UNDP (2011) assessed the green employment potential in Lebanon for five sectors: energy, construction, waste management, agriculture and forestry. In the energy industry, the report estimates that around 4,000 jobs would be created by 2020 through the introduction of concentrated solar power, wind energy, photo-voltaic solar and by expansions of hydraulic power and solar water heater markets. Additional employment effects would be due to the introduction of renewable energy systems in manufacturing.

Vidican Auktor (2017) reviews the development of renewable energy based on solar, wind, and hydro energy in Morocco as a green industrial policy. The earliest experience of Morocco with renewable energy stems from the Programme d'Électrification Rurale Globale (PERG) introduced in 1996. The programme increased rural electrification to 98 per cent in 2010. Estimates suggest that 13,000 direct and indirect jobs were created through the programme in 2006 (Vidican Auktor 2017, this volume). The Noor-Ouarzazate solar power complex represents the biggest renewable energy project in Morocco and is being built in phases with Noor I concentrated solar power being connected to the power grid in 2016. It created approximately 1,800 jobs in the construction process and 250 permanent operations jobs. Noor II, III and IV concentrated solar power are expected to go online in 2017 and 2018. The African Development Bank estimates that the construction of Noor 2 creates 2,000 to 2,500 jobs temporarily in the construction sector with 400 to 500 permanent operation jobs (IRENA 2016). Additional projects have been completed in Tarfaya, where Africa's largest wind farm was established. The wind farm went online in 2014 and 700 construction jobs were created during the construction process. Additionally, 50 operational jobs were established by the Tarfaya Wind Farm (IRENA 2016). Beyond renewable energy generation, Siemens built a factory in Morocco producing rotor blades for onshore wind turbines. Siemens (2016) estimates that its new factory will create up to 700 jobs.

Lastly, Borel-Saladin (2013) focus on South Africa, where the Green Economy Accord was signed in 2011 with the aim of creating at least 300,000 green jobs. Official estimates suggested that 98,000 net jobs would be created in the short-run, and an additional 462,567 net jobs in the long-run. The big driver of this increase would be natural resource management. However, the lack of skilled labour might impede growth.

Overall, this review of developing country documentation reveals how difficult it is to estimate the employment impacts of green transition and to compare development across countries, with the notable exception of renewable energy generation. It is in this sub-sector where green job gains are substantive and visible. Other green occupations, such as those related to pollution control and resource efficiency or circular economy investments, may increase more slowly or may have remained below the radar given that fewer statistics are available. To what extent green employment will increase in such areas will of course depend on the level of ambition of green industrial policies and related environmental incentive schemes.

4.3. WHICH INDUSTRIES ARE LIKELY TO UNDERGO MAJOR EMPLOYMENT TRANSFORMATIONS?

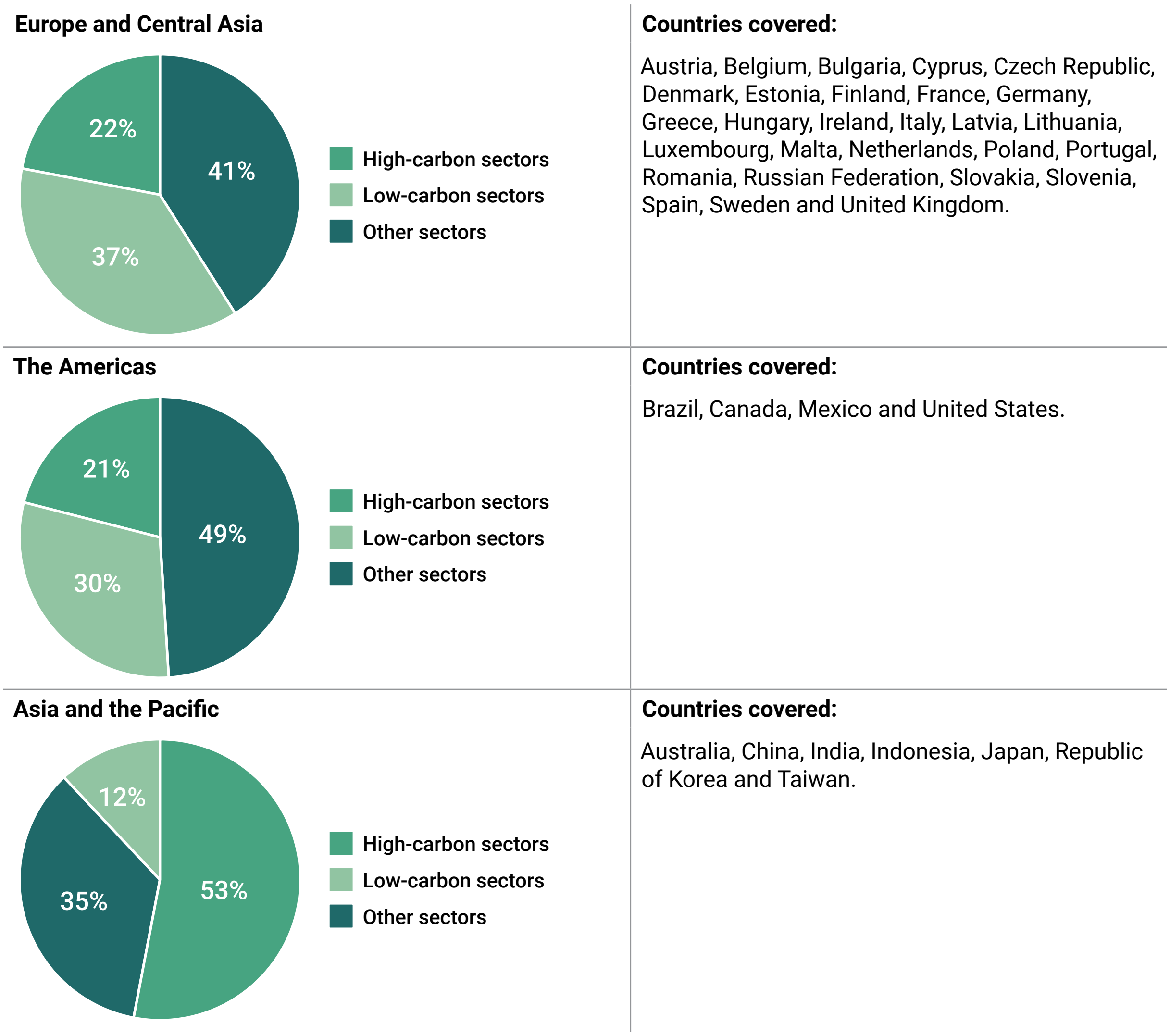
So far, evidence for job gains has been sought in narrowly defined employment categories, particularly renewable energy and other EGSS. Yet green transformations go along with technological change and shifts in relative prices that affect demand for labour and skill requirements in virtually all industries. Effects may be direct and indirect, and the outcomes in terms of job quantity and quality may be positive or negative, all of which is difficult to predict.

The magnitude of the employment challenge in green transformation can be estimated by determining the share of workforce in carbon-intensive sectors. People working in these sectors will have to go through some transition. Either these carbon-intensive sectors become greener through technological change such as an energy sector shift from fossil fuels to renewable energy or the respective sector will have to shrink. In the first case, workers in these sectors are likely to have to adapt or modify their skills and working methods, or to change enterprises. In the second case, workers find fewer jobs in the sector and have to move to other, greener sectors. The same applies to other unsustainable activities if environmental policies provide the respective signals, such as agricultural subsectors that deplete soil fertility and water or reduce biodiversity.

To estimate this challenge, exemplified for the decarbonisation challenge, this section utilizes data from the World Input-Output Database (WIOD). The database has been constructed by merging information from National Input-Output tables and Socio-Economic Accounts for the period 1995 to 2011, along with Environmental Accounts in the years 1995 to 2009. Using CO_2 intensity as a metric, it can be seen that most GHGs originate from just a few industries. Top carbon-emitting sectors are similar in all 40 countries for which data are available and include the energy sector, agriculture, transport, and heavy manufacturing (Appendix).

As these sectors are responsible for more than 80 per cent of GHG releases, the employment challenges would mostly concern these top emitters, the high-carbon sector (HCS). The share of GHG emissions of the HCS ranges from 79 per cent of total GHG emissions in the Americas to 89 per cent in Asia and the Pacific, using ILO regional classification. Conversely, the contribution of low-carbon industries (LCS) to total GHG emissions is very small, especially in Asia and the Pacific, and always below 10 per cent.

Figure 4.3: Share of CO_2 emissions by industry and ILO region



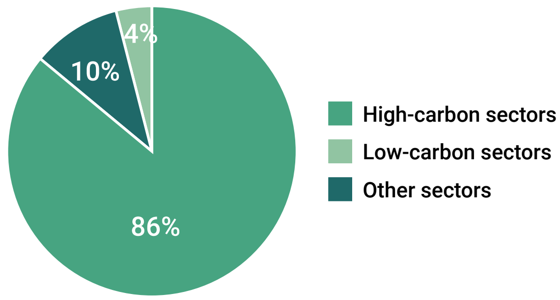
Source: ILO Research Department based on the World Input-Output database (WIOD 2013).

Note: Last available year: 2009. Africa and Arab States are not included because of lacking data availability. High-carbon sectors include the top ten listed in the Appendix. At the same time, low-carbon sectors include the top ten listed in the Appendix. All the remaining sectors are classified as other sectors.

According to ILO (2013), the top fifteen carbon-intensive industries in high-income countries employ a relative small share of workers. The largest share of the employed workforce in industrialised countries is not in the HCS. However, still about every fifth worker, 22 per cent, works in a carbon-intensive sector that will be, or is already, affected by green transformation. By contrast, carbon-intensive sectors are the largest providers of employment in Asia and the Pacific, accounting for 53 per cent of the workers in the sample (Figure 4.3). This discrepancy is due to the large employment shares in the agricultural, forestry and fishing sectors in developing and emerging economies. The employment shares for these three sectors can be between 30 and 80 per cent, depending on the country, and all of these natural-resource exploiting sectors are generally categorized as carbon-intensive. It should be noted that this classification only provides a rough approximation, given enormous differences of carbon-intensity within highly aggregated natural-resource sectors: whether and to what extent agriculture or forestry actually emits carbon, or even sequestrates it, depends on the way the sector is operated.

Figure 4.4: Employment shares in GHG emitting industrial sectors by region

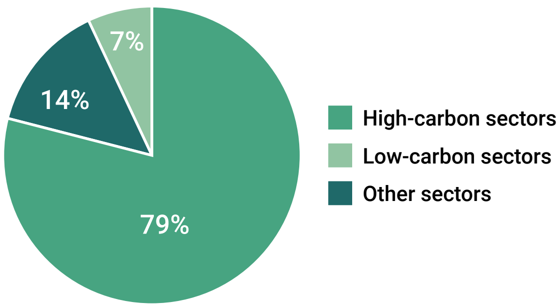
Europe and Central Asia



Countries covered:

Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden and United Kingdom.

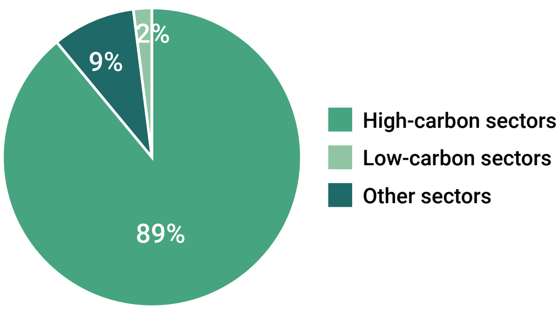
The Americas



Countries covered:

Brazil, Canada, Mexico and United States.

Asia and the Pacific



Countries covered:

Australia, China, India, Indonesia, Japan, Republic of Korea and Taiwan.

Source: ILO Research Department based on the World Input-Output database (WIOD 2013).

Note: All charts refer to the year 2011 (last available data point). Africa and Arab States are not included because of lacking data availability. High-carbon sectors include the top ten listed in the Appendix. At the same time, low-carbon sectors include the top ten listed in the Appendix. All the remaining sectors are classified as other sectors.

Still, these estimates highlight the challenges faced by developing and emerging economies in terms of employment. In industrialised countries, mainly heavy industries and the energy sector are going through the green transformation, with relative small employment shares; in developing and emerging economies, a much larger proportion of the work force will be affected. Policies therefore need to help workers to transition from the agriculture sector to productive, non-resource-intensive 'decent work' in other sectors of the economy.

5. POLICY OPTIONS TO STRENGTHEN LABOUR MARKET PERFORMANCE

Labour market challenges can be better addressed when effective policies are in place. Most labour market policies, including active as well as passive labour market tools, can support the efficiency and equity of economic transformations. Green industrial policies should therefore have employment and social policy components. Good jobs and business success in emerging green sectors are interdependent. On the one hand, workers want to benefit from new and decent jobs; on the other hand, only if workers are well-trained, mobile enough and prepared to take on new challenges can a green transformation be successful.

5.1. MOBILITY ASSISTANCE AND SKILL ADJUSTMENTS

The workforce needs to be allowed, and encouraged, to successfully shift through a green transition. The ability to manage transitions successfully is included in the ILO work under the term workforce mobility. Such mobility can take various forms. Workers need empowerment to fulfill new assignments or take on new jobs within the same enterprise, for example in an electric utility company that shifts its operations from fossil fuel based energy to renewables. Workers may also have to change jobs, leaving the enterprise but remaining in the same industry, or they may have to shift to different sectors.

To facilitate these transitions, dedicated enterprises should be supported in establishing training systems to ensure that employed and unemployed workers can upgrade and adjust their skills or even be retrained as needed. Reform of education systems may also be necessary, especially to help young workers enter the labour market. Public employment services can help re-allocate job seekers to open positions.

Geographical mobility should also be supported, especially when massive shifts of the industry structure result from green industrial policies. This may be the case, for example, when shifting from fossil to renewable energy: Fossil energy plants are usually located next to energy-intensive industries and cities, whereas renewable power plants are located where the respective power resources are abundant. Shifting energy systems will therefore affect spatial distribution, and workers will have to move physically (ILO 2011).

5.2. PROMOTING ENTREPRENEURSHIP

Green transformation will not necessarily be driven by large, existing firms. It offers opportunities for start-ups and small firms that develop new ideas and green innovations. In this regard, employment considerations should not only concern employees but also the promotion of self-employment and entrepreneurship. Green industrial policies should include a variety of measures for that purpose, for example to improve access to credit or support the formalization of informal enterprises, which is particularly important in developing countries.

5.3. REVENUE-NEUTRAL GREEN TAXES

Empirical evidence suggests that levying environmental taxes while reducing taxes on labour produces positive employment effects (Schlegelmilch et al. 2017, this volume). This approach, called revenue recycling, increases economic efficiency by internalizing environmental costs. Considering the economic consequences in isolation from social and health benefits, three interacting effects must be managed wisely: the primary cost of the introduction of new green taxes will reduce economic activity; revenue recycling will have a positive effect on the economy; and levying new taxes on top of already existing taxes that interact with the existing taxes will add additional costs (Goulder 2013). Thus, from a purely economic perspective, the potential of an economic expansion depends on the strength of the revenue recycling effect, in relation to the sum of the first and third effects.

The first effect has been discussed widely in the context of high-income countries. The Canadian province of British Columbia introduced a revenue-neutral carbon tax in 2008 with reductions in corporate and personal income taxes, and with lump-sum payments to low-income households. Yamakazi (2015) reports that emission-intensive and trade-exposed industries suffered from falling employment opportunities due to the new tax, while other sectors increased their employment, suggesting a movement of labour between sectors. On an aggregated level, he concludes that the tax reform had positive effects on employment. In Germany, green taxes have been recycled to cut pension contributions, thereby lowering labour cost. Estimates suggest that the green tax reform created around 250,000 jobs in 2003 alone (EEA 2011).

Verifiable evidence for lower and middle-income countries is very limited. Findings from high income countries may not be representative of developing countries because of differences in factor prices, endowments and labour market characteristics (Bowen and Kuralbayeva 2015). Importantly, the economies of many developing countries are characterized by large informal labour markets. Kuralbayeva (2013) focuses explicitly on modeling labour market characteristics of developing countries with an informal sector and rural-urban migration. She concludes that revenue-neutral green tax policies can reduce unemployment in the private sector: by using the additional government income to reduce payroll taxes, the cost of employment in the formal sector decreases. At the same time, environmental taxes decrease the income of self-employment in the informal sector. Thus, in the model, the tax burden shifts towards the informal sector, which then creates incentives to operate formally and reduces formal unemployment (Kuralbayeva 2013).

Landa Rivera et al. (2016) assess the effect of carbon taxes and revenue recycling on the Mexican economy. They conclude that such reform would be beneficial for the economy and the environment, yielding a double dividend: emissions would decrease, while GDP, employment, wages, but also inflation, would increase. Schlegelmilch et al. (2017) suggest that revenues should be recycled in ways that meet the respective national priorities and enhance political support for environmental tax reforms.

5.4. DECENT WORK AND SOCIAL DIALOGUE

Social dialogue is a mechanism through which interested representative groups, such as trade unions and business associations, and the government aim to build consensus among major stakeholders. Effective dialogue can help resolve crucial social and economic issues and improve economic performance. Given that the transition towards a greener economy will entail profound changes in production processes and technologies, as well as reallocations of jobs, close cooperation between government and the social partners will be central to the success of this transformation (ILO and UNEP 2012).

A greener economy does not automatically create high-quality, decent jobs. Job quality needs to be monitored and measures taken to ensure that labour legislation is applied and workers and employers can organize and make use of collective bargaining. In this regard, International Labour Standards provide both a legal and institutional framework and practical guidance for work in a greener and more sustainable economy. Similarly, while a green economy is very likely to be healthier and safer for workers and the public, caution is nonetheless needed to prevent possible new occupational hazards (ILO and UNEP 2012).

6 CONCLUSIONS

A green structural transformation creates opportunities for more and better jobs, but it also poses challenges for employment and incomes. To evaluate the impacts of green transformation on employment, various definitions of green jobs are in use. Many statistical agencies use a narrow definition covering only sectors involving environmental goods and services. Looking at EGSS only, studies for the EU, the United States and other countries have demonstrated the potential for the environmental sector in job creation. Annual green job growth rates vary, but have been as high as 37 per cent in the case of Germany. The share in total employment ranges between 1 to 4 per cent.

However, when studying overall employment effects of green transformations, it does not suffice to look at the emerging green sector in isolation. Greening sectors, occupations and jobs may happen in other sectors as well, and the narrowly defined EGSS may have spillover effects on other activities. While on the one hand new green jobs emerge, there will also be job losses in polluting industries. Estimations have shown that between 20 to 50 per cent of workers worldwide are currently still working in carbon-intensive industries, where the need to change business models, jobs and occupations is particularly acute. Thus, for a full appraisal of employment effects, detailed subsectors and general interaction effects between sectors need to be considered. EGSS figures only capture a small part of the labour market change.

Moreover, employment considerations should not only focus on the number of jobs created or lost but also the quality of jobs. The ILO Decent Work Agenda–encompassing job creation, rights at work, social protection and social dialogue–can offer guidance on how the green economy should provide 'decent work' and be socially inclusive. To emphasize this agenda, ILO's definition of green jobs limits the concept to those jobs that can also be considered as 'decent work'.

Labour market and social policies, in particular active and passive labour market policies, can and should support successful green transformation by enhancing the mobility and skills of workers. Compliance with International Labour Standards in all sectors of the green economy can ensure commitment to job quality. Finally, well designed revenue-neutral green tax policies can have positive effects for the environment and employment.

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APPENDIX

This Appendix illustrates the methodology underlying the figures and tables presented in the chapter. Data on GHG and employment by sector were taken from the World Input-Output Database (WIOD), 2013 release. The WIOD has been part of a project funded by the European Commission and officially launched in 2012. The core of the WIOD has been constructed by linking national supply and using tables with statistics in international trade (Erumban et al. 2011). It also includes socio-economic accounts, employment and environmental indicators on resource use and emissions (WIOD 2017).

CO_2 emissions are calculated in the form of CO_2 equivalents and therefore include also other GHG emissions. The WIOD contains information on other emissions and resource utilisation such as energy use, water consumption, or material use. Unfortunately, only GHG emissions and energy consumption are systematically available for most industries and across countries. Energy consumption and GHG emissions are highly correlated and lead to a similar ranking. Water consumption and material use are only available for a limited number of industries. While the available information on water consumption and material use is in line with the ranking based on GHG emissions, there are too many missing data points to establish a ranking on resource-intensity.

To conduct the analysis, information coming from the national input-output tables is merged with data on social and economic accounts for the period 1995 to 2011, along with environmental indicators for the years 1995 to 2009. In total, data is available for 35 industrial sectors based on the ISIC rev.3 classification in 40 countries (United Nations Statistics Division 2017). The database also includes information on emerging and developing economies for which detailed sectorial information is typically difficult to find. In particular, 33 countries are developed economies, 5 are upper-middle and 2 are lower-middle income countries. In addition, 13 out of the 40 countries are not OECD members, while 12 countries are not EU members.

The following countries are included in the analysis of the chapter: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malta, Mexico, Netherlands, Poland, Portugal, Romania, Russia, Slovak Republic, Slovenia, Spain, Sweden, Taiwan, United Kingdom and USA.

GHG EMISSIONS IN TERMS OF CO_2 EQUIVALENTS

Methane and nitrous oxide are converted into their CO_2 equivalents in order to have a measure of the total GHG emissions produced by a given industry in a particular country. CO_2 equivalents are estimated through the Brander (2012) formula, where:

> CO_2 equivalents= tons of the gas x global warming potential[11] of the gas.

CO_2 emissions are summed up with methane and nitrous oxide in CO_2 equivalents to get the total GHG emissions.

EMISSION INTENSITIES

Following ILO (2011), direct CO_2 intensities are estimated as ratio of GHGs measured in kilotons over the total output in millions of US dollars. A sector is classified as high-carbon (HCS) if its CO_2 intensity is above the median or as low-carbon (LCS) if its CO_2 intensity is below the median.

Six countries are included in the analysis: France, Germany, United Kingdom, United States, China and Brazil. The reference year is 2009. Results show that the majority of industries is always high or low-carbon intensity, independently of the country taken into account. At the same time, its relative ranking is quite stable across countries. This result is consistent with ILO (2011) and it points out that the level of technological progress in a given industry is similar across countries. The top ten high and low-carbon sectors according to their CO_2 intensity levels and their relative frequency in the cross-country comparison are presented (Table 4.1).

11 The Global Warming Potential (GWP) indicates the amount of global warming a gas causes over a given period of time, relative to CO_2 (Brander, 2012). The period of reference is usually 100 years. The higher the GWP the most dangerous the gas with respect to CO_2. Data on the GWP come from IPCC (2007).

The authors also analyze the change over time in emission intensities. France is the reference country. Three years are taken into account: 1995, 2003 and 2009. The analysis shows that the relative ranking of few industries changes over time. However, changes are quite limited: none of the top polluter industries shifts into the low-carbon category from one year to the other.

Table 4.2: Top ten HCS and LCS in the last available year.

HCS	LCS
Agriculture, hunting, forestry and fishing	Electrical and optical equipment
Air transport	Financial intermediation
Basic and fabricated metals	Health and social work
Other community, social and personal services	Machinery
Mining and quarrying	Post and telecommunications
Other non-metallic minerals	Real estate activities
Electricity, gas and water supply	Renting of M & Eq. and other business activities
Water transport	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
Inland transport	Transport equipment
Coke, refined petroleum and nuclear fuel	Wholesale trade and commission trade, except of motor vehicles and motorcycles

Source: ILO Research Department based on WIOD.

Note: Last available year: 2009.

EMPLOYMENT SHARES

Employment shares are estimated using the average of employed persons by sector and area in a particular year. The estimates are, then, divided by the total employment in a particular region to get the share.

PART 3:
ACCELERATING CHANGE

CHAPTER 5

IN WITH THE GOOD, OUT WITH THE BAD: PHASING OUT POLLUTING SECTORS AS GREEN INDUSTRIAL POLICY

Aaron Cosbey, Peter Wooders, Richard Bridle, Liesbeth Casier

1. INTRODUCTION

Industrial policy, broadly cast, can be defined as, "a set of policies that selectively favours the development of certain industries over others" (Schwarzer 2013). Green industrial policy, more specifically, is defined as (Altenburg and Rodrik 2017, this volume):

"comprising any government measure aimed to accelerate the structural transformation towards a low-carbon, resource-efficient economy in ways that also enable productivity enhancements in the economy".

Cosbey (2013) describes green industrial policy as supporting the development of domestic industries that produce green goods, or goods that:

- have better environmental performance in operation than their competitors including electric vehicles, renewable electricity-generating equipment, energy-efficient appliances
- directly address environmental problems such as environmental remediation technologies
- are produced in a way that is environmentally preferable to their competitors as in the case of organic agriculture.

By far the majority of green industrial policy over the last decades—in China, India, Germany and Denmark, for example—target the development of new low-carbon energy technologies, such as solar photovoltaics, wind turbines and power storage (Buen 2006; Lewis and Wiser 2007; Wang et al. 2010; Zhang and He 2013; Lütkenhorst and Pegels 2014; Ganesan et al. 2014; Vidican Auktor 2017, this volume). This is understandable, given their significant recent growth in demand and enormous near-term potential for further growth (IEA 2015a; IEA 2015b; BNEF 2016). But green industrial policy goes beyond renewable energy to cover a wide range of environmental sectors such as transportation technologies, especially electric and low-emission vehicles and batteries; low-GHG emission waste management operations; drought- and salt-resistant plant varieties; water-saving technologies; and technologies for heating, cooling and energy conservation in buildings.

The case studies in this volume, and most of the broader discussion around green industrial policy, are concerned either with measures taken to enhance the business environment in which new domestic industries might flourish, or with more targeted assistance for particular sectors. In both cases, the green industrial policy mechanisms employed are positive measures, encouraging the development of specific sectors through support, incentives and complementary enabling measures.

This chapter deals with industrial policy of a different type. It explores the ways in which governments might support green industrial development by primarily negative measures—that is, by measures that seek to diminish the role of certain sectors within the economy, phasing them out and thereby fostering space for green sectors to operate and compete. Lütkenhorst et al. (2014) and Altenburg and Pegels (2012) discuss this sort of green industrial policy strategy as 'pathway disruption': the dismantling of key polluting sectors of the economy to allow the growth of greener alternatives. These authors argue the importance of disruptive green industrial policy: it targets sectors that are environmentally harmful, and thus need to be phased out.

The harmful sectors most in need of active disruption are locked in, and have the financial power and political clout to frustrate urgently needed restructuring. As well, these sectors merit attention because they tend to be deeply embedded in the social and economic fabric—the oil and gas industry and associated transportation and power sectors are good examples. As such, their eventual dissolution implies significant transition costs that should be anticipated and appropriately managed. This is especially important to avoid particularly negative effects on already disadvantaged groups such as the women and youth in a society.

The following section defines what is meant by 'disruptive green industrial policy', describing some of the tools that can be used to achieve it and offering a spectrum on which various green industrial policy efforts might be focused. Section 3 offers several case studies of green industrial policy, aiming to draw from them lessons that can be applied more broadly. Section 4 then uses those lessons to generate policy guidance that should be useful to decision-makers. Section 5 concludes.

2. DEFINING DISRUPTIVE GREEN INDUSTRIAL POLICY

What we will call disruptive green industrial policy is defined as: measures to restrict or phase out environmentally undesirable sectors in such a way as to provide opportunity for greener sectors to prosper. Like the other forms of green industrial policy discussed within this volume, disruptive green industrial policy seeks to promote green industrial development within the implementing jurisdiction. It is properly understood as a complement to the more familiar positive sort of green industrial policy insofar as it facilitates the desired growth in green sectors by making room for them to flourish.

There are many tools that might be used in the practice of disruptive green industrial policy, to help phase out targeted sectors:

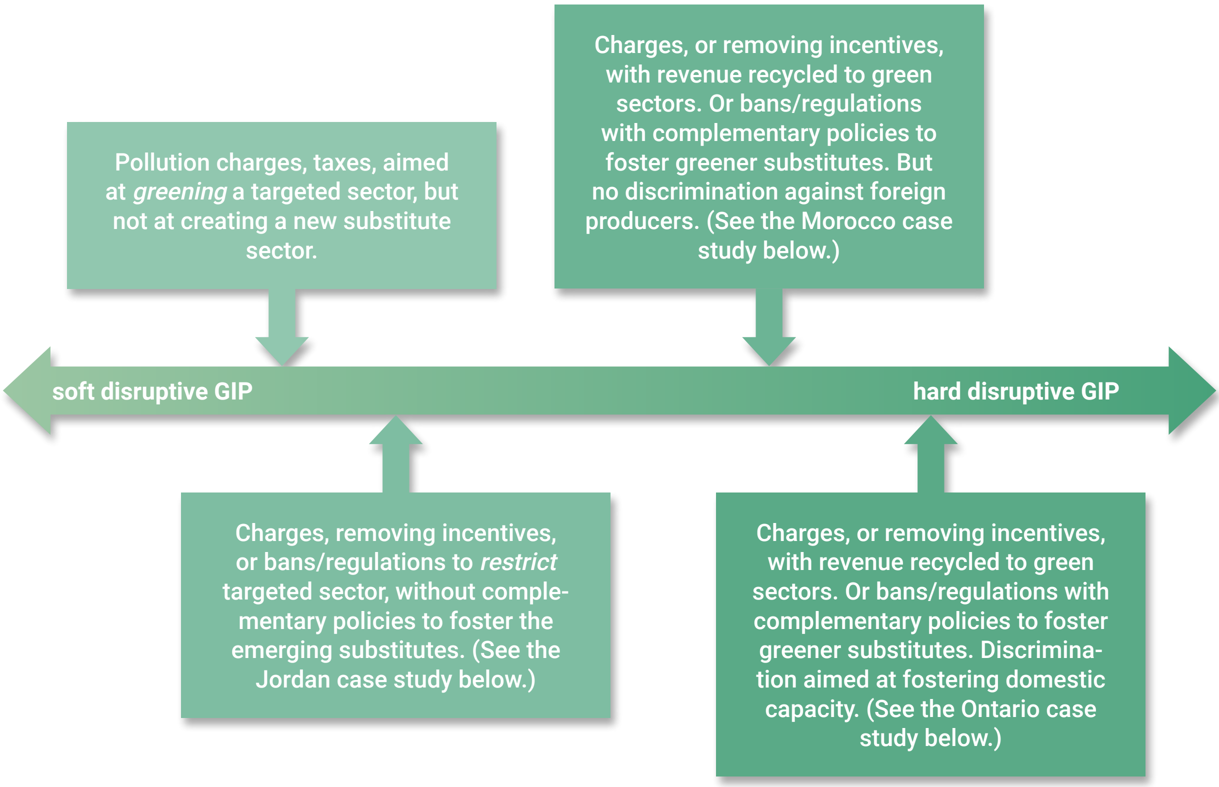
Environmental taxes, charges, levies, fees: Any sort of financial burden placed on firms and sectors will decrease their competitiveness relative to other actors in the economy. If the burden is aimed at correcting negative environmental externalities, then the effect is to encourage economy-wide structural change toward a greener state, and to enhance the economic viability of competing green firms and sectors. As such, disruptive green industrial policy bears some resemblance to fiscal reform, when it seeks to increase taxes on those things that society wants less of and reduce taxes on those things that society wants more of, preferably in a revenue-neutral fashion. In the case of green industrial policy, society wants less pollution and resource waste and more employment and income (Stoianoff et al. 2016; Hanna et al. 2012; UK Green Fiscal Commission 2009; Schlegelmilch et al. 2017, this volume).

Elimination of incentives: Another set of tools removes incentives granted to sectors targeted for phase out. These might be financial incentives or subsidies such as cash grants, low-interest loans, loan guarantees, limits on liability, price supports, purchase mandates, various types of tax breaks. They can also include free or low-cost inputs such as land, grants of dedicated infrastructure or support of research and development efforts. Incentives might also be regulatory, as when specific firms are granted exclusive marketing rights or concessions. Removing these sorts of incentives to targeted firms or sectors has the same effect as imposing taxes, charges, levies or fees: it renders them less viable relative to greener competitors, and moves the economy toward a greener mix of economic activity. Removing fossil fuel subsidies, for example, makes renewable energy substitutes more competitive and guides the economy toward consumption of less polluting final goods through price signals. Removing tax advantages for energy- and material-intensive sectors amounts to restructuring the economy in favour of greener, high-value added firms.

Mandated phase out: The most powerful set of tools force a mandated phase out of the targeted sector or firms. This is demonstrated by the mandated phase out of coal-fired electricity generation in Ontario, Canada. Where, as in the Ontario case, the targeted sector is the domain of government agencies, the phase out involves a policy decision to end the operation of the sector's operations. Where private interests operate the sector, a phase out will involve regulatory and legal bans or restrictions on sales or operation, as in the phase out of lead as a paint additive in most OECD countries.

There is a spectrum of types of disruptive green industrial policy, with the differentiating factor being the level of effort devoted to promoting the sectors that will benefit from the diminished role of the phased out activities. As noted above, disruptive green industrial policy is characterized by the intent to not only reduce undesired types of activity, but to also promote more desired types of domestic economic activity. Figure 5.1 illustrates this spectrum.

Figure 5.1: Spectrum of Types of Disruptive Green Industrial Policy



At the left end of the spectrum, representing soft policy, exist policy options that diminish the role of undesirable activities with the explicit understanding that simply by doing so some green sectors will be enabled. An example of this type of policy is a carbon tax, which by itself would benefit a broad variety of green firms and sectors, but which attempts to neither identify particular targets for phase out, nor chart the course of the transition in the direction of particular domestic champions. Further across the spectrum would be the reduction or elimination of fossil fuel subsidies. These tend to be targeted at specific firms and sectors, and the resulting beneficiaries will also be specific: for example, renewable energy generators and the related input manufacturers and services. But these beneficiaries may be domestic, or they may be foreign exporters of green goods. At the right end of the spectrum, corresponding to what we have called hard disruptive green industrial policy, are policies that combine deliberate phasing out of target sectors with deliberate cultivation of substitute domestic sectors. An example of this is the phase out of coal-fired electricity generation in Ontario, Canada and the concurrent promotion of domestic renewable energy sectors.

3. EXAMPLES OF DISRUPTIVE GREEN INDUSTRIAL POLICY

This section relates four examples of disruptive green industrial policy, aiming to both illustrate the types of approaches described above, and to draw lessons from specific cases that might be useful guidance in a more general context. It covers fossil fuel subsidy reform, including brief case studies of subsidy reforms in Jordan (Box 5.1) and Morocco (Box 5.2), China's reform of value added tax refunds to polluting and resource-intensive sectors (Box 5.3), and policies in the Canadian province of Ontario to phase out coal and promote renewables (Box 5.4).

3.1. FOSSIL FUEL SUBSIDY REFORM

Fossil fuel subsidy reform has been on the international agenda since the 2009 G20, when those countries committed to phasing out inefficient fossil fuel subsidies (G20 2009). A number of similar declarations have followed, including

Sustainable Development Goal 12, Target C, where the signatories committed to "rationalise inefficient fossil-fuel subsidies that encourage wasteful consumption" (UN 2015).

Fossil fuel subsidies can be broadly divided into two types: those delivered to consumers through artificially low retail prices and those delivered to producers of fossil fuels as grants, low-interest loans, preferential tax treatment or other such measures.

While the World Trade Organization's Agreement on Subsidies and Countervailing Measures has a legal definition of subsidies in general, more useful here is the definition of fossil fuel subsidies offered by Kojima and Koplow (2015) "measures that target fossil fuels, or fossil fuel-based electricity or heat, and cause one or more of the following effects: a reduction of net energy costs, a reduction of energy production or distribution costs, and an increase in the revenues of energy suppliers".

There are a number of estimates for the magnitude of global fossil fuel subsidies, ranging from US$ 250 million to US$ 5 trillion, depending on the definition used (Kojima and Koplow 2015). The high end of those estimates comes from the International Monetary Fund (2013a) based on a definition that includes external costs of fossil fuel use such as the social cost of carbon and health costs of air pollution.

While the precise figure is difficult to determine–given the different ways of defining subsidies–there is no disagreement about the resulting environmental impacts. Consumer subsidies artificially lower the price of fossil fuels, encouraging over-consumption. This lowers incentives for conservation or for efficiency investments, as well as reducing the viability of investment in substitutes such as renewable energy sources. That viability is already impaired by the fact that fossil fuel power sector investments are locked in for many decades. Producer subsidies lower production costs, enhance profits, and invite further investment in fossil fuel exploration and extraction, as well as for the research and development that produces technologies that further lock in the fossil fuel power sector.

Eliminating fossil fuel subsidies would have a palpable effect on global GHG emissions. Terton et al. (2015) note that 13 countries included fossil fuel subsidy reform in their Paris Agreement commitment to Intended Nationally Determined Contributions. Burniaux and Chateau (2014) estimate that eliminating fossil fuel subsidies would cause an 8 per cent reduction in GHG emissions by 2050. Schwanitz et al. (2014) estimate a 6.4 per cent decrease by 2050. Merrill et al. (2015) model subsidy removal in 20 countries and find an average GHG emissions reduction of 11 per cent by 2020. It is worth noting that all these figures likely understate the true extent of effects, since they focus only on a demand response to price increases and do not consider the effects of producer subsidies or investment distortions.

Box 5.1: Jordan's fossil fuel subsidy reform

Jordan imports almost all of its natural gas and oil. In 2005, after several years of spiking international prices and controlled domestic prices, the annual cost of sheltering domestic consumers, power generators and industry had reached an unsustainable 5.8 per cent of GDP, or US$ 711 million (Bridle et al. 2014). Over an implementation period of seven years, the country gradually but completely eliminated its subsidy programmes, eventually allowing domestic prices to be objectively set monthly by a formula that reflects international prices.

This was the third time in 30 years the government had tried to reform its energy-pricing regime, with the first two ending unsuccessfully after massive public protests. Several elements helped ensure that this time the effort would succeed (Fattouh and El-Katiri 2012):

- The reform was announced well in advance and implemented over a long time frame.
- The government took great pains to educate Jordanians about the need for change and the unsustainability of the status quo.
- Public sector wages and pensions were increased, with higher increases for low-income earners, and private sector low-wage earners were separately compensated. Almost 60 per cent of the population benefited under these schemes. The poor received further food subsidies and social safety net programmes were enhanced.

- Fossil fuel subsidy reform was pursued as part of a broader energy sector reform, wherein the electricity sector was rationalized, unbundled and made to charge end users the true costs of generation and distribution.

Measures to mitigate the consequences of reform were only taken after it became obvious that they were creating substantial difficulties for households and industry, particularly for low-income households (Fattouh and El-Katiri 2012). Despite the government's efforts to communicate the need for reform, the initial effects sparked massive protests.

Jordan did not attempt to phase in greener alternatives in parallel with its reform efforts. This meant that while consumption dropped in response to price increases—a significant environmental outcome—there was no growth in new green sectors, much less domestic green sectors. While both CO_2 emissions and emissions per unit of GDP dropped from 2005 to 2009, both have since steadily increased (Merrill et al. 2015).

Box 5.2: Fossil fuel subsidy reform in Morocco

Morocco imports over 90 per cent of its primary energy sources (IEA 2014a). In 2000, the country suspended international indexing of consumer prices of gasoline, kerosene, diesel and liquid propane gas (LPG), in an effort to shelter consumers from climbing world prices. Gradual domestic price increases kept the fiscal cost of these subsidies low until 2009, but international price spikes thereafter led to an unsustainable subsidy expenditure of 6.6 per cent of GDP by 2012 (Merrill et al. 2015)

The government began the process of subsidy reform in 2013, but retained subsidies that it deemed to be sheltering the poor, such as those for electrical generating fuel and LPG. In 2014, it removed all fuel subsidies but those for LPG, though diesel subsidy reform is on a slow timetable (IEA 2014a). Electricity prices are still regulated to be lower than production costs.

The government learned from previous unsuccessful reform efforts, undertaking a massive public information campaign and increasing support for the poor, who were proportionately much more threatened by the price increases. A conditional cash transfer programme targeting poor rural households expanded from 80,000 families in 2009 to 466,000 families in 2014. A health insurance scheme for the poor increased its coverage from 5.1 million beneficiaries in mid-2013 to 8.4 million beneficiaries in early 2015 (Merrill et al. 2015).

At the same time, the 2009 National Energy Strategy included the objective of accelerating development of renewable energy, targeting a 42 per cent share of total mix for renewables by 2020, or 2 GW each of wind, solar and hydro capacity. Since then, the government has invested in research and development for renewables and attracted major investments, including the world's largest concentrated solar power plant, the first phase of which came on line in 2016 (IRENA 2016b), and roughly 750 MW of new wind capacity (IRENA 2016a). In 2016, a consortium was awarded a concession to build 850 MW of wind power capacity over 5 projects. As part of the deal, Siemens—one of the consortium partners—will invest US$ 110 million in a domestic manufacturing facility for turbine blades, intended for both domestic use and export to Africa and Europe (Yaneva 2015). Morocco's efforts to strengthen its renewable energy potential are further discussed in a dedicated case study in this book (Vidican Auktor 2017, this volume).

These environmental outcomes—and in particular the consequences for the competing renewable energy sector—are the basis of the argument that fossil fuel subsidy reform can be thought of as disruptive green industrial policy. Fossil fuel subsidies crowd out investment in renewable energy in several ways, primarily by making its competitors cheaper (Bridle and Kitson 2014; Bazilian and Rentschler 2016). IEA (2014b) estimates that in the Middle East oil subsidies reduce the costs of generating electricity from new oil-fired plants to 30 per cent of what they otherwise would be, and gas subsidies reduce those costs to 45 per cent of the unsubsidised levels. Elsobki et al. (2009) argue that while Egypt has excellent wind regimes, investment in wind power there is not viable because of subsidies granted to gas-fired electricity producers. While many countries undertake fossil fuel subsidy reform primarily in pursuit of fiscal savings, there can be a robust mix of motivations that may include the promotion of renewable energy, as in Morocco. The International Monetary Fund (2013b) notes that promoting renewable energy was one of the key objectives behind the reform of fossil fuel subsidies in Kenya.

The two cases of Jordan and Morocco make it clear that fossil fuel subsidy reform can be situated at various places along the spectrum described in Figure 5.1, depending on the particulars of the effort. Jordan's reform efforts evened the playing field for renewable energy investment in the country, but they are situated toward the soft end of the spectrum, since there was no accompanying drive to foster those greener alternatives. Fossil fuel subsidy reform in and of itself, absent complementary policies aimed at simultaneously fostering domestic renewable energy manufacturing capacity, does not guarantee the emergence of green substitutes. In the case of Jordan, the lack of subsequent renewable energy investment can be interpreted as testimony to the multiple obstacles that such investment faces beyond price competition with conventional fuels, such as legal and regulatory barriers, and financing.

By contrast, Morocco engaged in dedicated efforts to attract this sort of investment in parallel with its reform efforts, with resulting growth in its renewable energy sector. This situates the Moroccan case to the right of Jordan's case on the spectrum. In the case of Morocco, the linkage between phase out and promotion was part of the broader vision, as enunciated in the 2009 National Energy Strategy. But the linkage was also financial: the investments in renewable energy support were made possible by the savings from fossil fuel subsidy reductions.

Furthest to the right on the spectrum would be cases where fossil fuel subsidies were removed, renewable energy was promoted, and domestic firms in the renewable energy sector were fostered. That is, while fostering renewable energy investment may promote domestic capacity, that result would be only one of many, and would by no means be certain. Other possible results, for example, might be simply increased imports of renewable energy technologies. In the case of Morocco, fostering domestic capacity was explicitly part of the strategy (Vidican Auktor 2017, this volume). The tools used included spending on domestic research and development and the requirement that access to lucrative wind power concessions was conditional on commitments to investment in domestic manufacturing.

It is noteworthy that both Morocco and Jordan had tried previously to reform their fossil fuel subsidy regimes, only to have those efforts scuttled by widespread public opposition. In both cases this was ultimately overcome by a two-pronged approach that included extensive public outreach and a redirection of the saved funds into social programmes and transfers designed to soften the price shock in particular for low-income consumers.

3.2. CHINA'S GREEN VALUE ADDED TAX REFORM

China has made great efforts to phase out energy-intensive, resource-consuming and polluting sectors by means of fiscal policy as part of a broader push to restructure along green economy lines.

China's desire for economic restructuring serves many objectives, including environmental but also including economic. The eleventh five-year plan covering 2006 to 2010–described by some as revolutionary and a turning point (Fan 2006)–had an admirable aim as one of its key elements. The policy planned to promote adjustments in industrial and economic structure and transforming economic growth from being driven by quantitative expansion of industry to being driven by balanced development of the primary, secondary and tertiary industries and by structural optimization and upgrading (Kai 2006).

Box 5.3: China's drive for a greener economy

China's first national climate change policy, China's National Climate Change Programme (Government of China 2007), set out as one of its objectives:

"to deepen institutional reform of foreign trade in controlling export of energy-intensive, pollution-intensive and resource-intensive products, so as to formulate an import and export structure favourable to promote a cleaner and optimal energy mix".

In a subsequent policy paper outlining the steps taken to implement the Programme, in a section entitled *Adjusting the Economic Structure to Promote the Optimization and Upgrade of the Industrial Structure*, the government (Government of China 2008) described its efforts as:

"Limiting the excessively rapid expansion of high energy intensive and emission intensive industries… By adjusting tax rebates for exports and customs duties, the government is working to restrain the export of high energy-intensive, pollution-intensive and resource-intensive products".

Set in the context of a broad programme of policies to address climate change, this effort was explicitly aimed at restructuring the national economy by discouraging polluting firms and sectors. It was accompanied by other efforts aimed at reducing inefficient production capacity that—in 2007 alone—led to the forced closure of 14.4 GW of small thermal electrical generating capacity, 46.6 million tons of iron-smelting capacity, 37.5 million tons of steelmaking capacity, 52 million tons of cement production capacity, as well as over 2000 small coal mines and heavily polluting papermaking plants, chemical plants, and printing and dyeing mills (Government of China 2008). These measures were accompanied by, among other things, a target to raise the proportion of renewable energy in primary consumption to 10 per cent by 2010 (Government of China 2008).

In 2010 the government cancelled export value added tax (VAT) refunds for a list of 406 energy-intensive products, effectively raising the cost of production and putting those sectors at a significant disadvantage relative to other export sectors (Wang et al. 2010). Up until that point a portion of the VAT paid domestically had been refundable at the point of export, a policy commonly used to promote exports.

In 2010 China cancelled value added tax refunds to a number of energy-intensive products, as part of the broader drive for economic restructuring along more sustainable lines. While this policy was not accompanied by specific support for greener domestic economic capacity, the intent was clearly to foster growth in lower-impact sectors such as the services sector and, coming as it did in the context of China's climate change policy, in the various renewable energy sectors. As such it sits toward the hard end of the spectrum of green industrial policies shown in Figure 5.1, but not very far in that direction.

This case, however, shows how problematic such distinctions can be. It is true that there were no policies linked to the value added tax reform that tried to promote substitute green sectors. At the same time, however, this policy came in the context of a myriad of government policies aiming to shape the Chinese economy along greener lines, including powerful support at the federal and local levels for domestic manufacturing capacity in solar and wind power (Wang 2010, Zhang and He 2013). In the context of that sort of support, any disruption of polluting sectors could be expected to have salutary effects on green domestic capacity, even absent explicitly stated objectives to that effect.

3.3. ONTARIO'S COAL PHASE OUT

At the hard end of the spectrum of green industrial policy approaches is the phase out of undesirable sectors accompanied by explicit efforts to support domestic capacity in the sectors' greener substitutes. The case of a phase out of coal-fired electricity generation in Ontario, Canada demonstrates a policy that was inextricably linked with efforts to establish a renewable-energy manufacturing sector in the province.

Box 5.4: Ontario's coal phase out and renewables support

The independent power regulator in Ontario, Canada's most industrialised province, described it as "the single largest greenhouse gas reduction measure in North America" (OPA 2007); the phase out of coal-fired electricity generation in that province saw the percentage of coal in the energy mix drop from 25 per cent in 2003 to zero in 2014.

The phase out had multiple objectives including protecting public health, reducing pollution and addressing climate change. Ultimately, though, a key element of the programme's political feasibility was the accompanying suite of green industrial policy measures that held the promise of jobs from green industrial development in the province, measures designed to replace coal-fired power with renewable power generated from components manufactured in province (Harris et al. 2015). Those measures included:

- a generous feed-in tariff programme for renewable power (up to US$ 0.80/kWh) with 20-year contracts, conditional on high use of Ontario-made components of between 50 and 60 per cent after 2012
- streamlining of the environmental approval processes for renewable energy projects
- net metering provisions to accelerate residential uptake of renewable energy generation
- the 2010 Green Energy Investment Agreement (Government of Ontario 2013), a partnership agreement between Ontario and a consortium led by Samsung, under which the consortium committed to investing US$ 7 billion in Ontario's solar and wind manufacturing sector, and to the development, construction and operation of 2,500 MW of solar and wind generation projects in the province, the power from which would be purchased by Ontario at guaranteed preferential prices
- the Long-Term Energy Plan (Ontario Ministry of Energy 2010) that set a target of 10,700 MW of wind, solar and bioenergy capacity to be added by 2021.

The coal phase out was accompanied by a suite of green industrial policy measures designed to promote renewable energy capacity in the depressed industrial heartland of Ontario. This was to have the effect of both replacing the lost coal-fired generating capacity–25 per cent of the generating mix in 2003–and developing a renewable energy sector. Foremost among the green industrial policy measures was a feed-in tariff regime for all types of renewables, with rates in the initial scheme ranging from US$ 0.10/kWh for large-scale landfill gas to US$ 0.80/kWh for residential-scale solar photovoltaic (OPA 2009). While many rates were later reduced, the latter is one of the highest premiums ever offered globally for any type of renewable energy.

Was the Ontario exercise in phase out green industrial policy successful? Given the multiple objectives, success would need to be assessed on a number of different levels.

In terms of dissemination of renewable energy generating capacity, the programme has been successful and will easily exceed the targets announced at the programme's outset. Significant changes have come about in the generating mix since the programme's inception (Table 5.1). The government's 2007 Long Term Energy Plan set the goal of doubling renewable generating capacity to 15,700 MW by 2025 (OPA 2007). By May 2016, the province already had grid-connected renewable capacity of 13,030 MW, with another 850 MW expected to be added over the subsequent 18 months (IESO 2016).

Table 5.1: Ontario's Electrical Generating Capacity (comparison 2010–2016)

	Total Installed Capacity (MW)		
	Aug 2010	**May 2016**	**% change**
Nuclear	11,446	12,978	13%
Hydroelectric	7,903	8,432	7%
Coal	6,434	0	-100%
Oil / Gas	8,792	9,942	13%
Wind	1,084	3,823	253%
Biomass / Landfill Gas	122	495	306%
Solar	0	280	-
Total	35,781	35,950	0.5%

Source: IESO 2010, IESO 2016.

These figures understate the growing share of renewables in Ontario since they do not include embedded capacity–capacity to produce electricity that does not go through the grid, such as rooftop solar panels and on-site wind turbines. In August 2010 embedded capacity in Ontario amounted to 700 MW (IESO 2010). In May 2016 there was 2,987 MW of renewable embedded capacity–a 427 per cent increase (IESO 2016). Adding embedded capacity in the figures, the total share of renewables in the May 2016 mix rises from 14.7 per cent to 24.2 per cent. However, renewables were not able to take up the entire burden of replacing coal's share of the generating mix; installed capacity of gas and nuclear have risen by much more than the percentage rise in total capacity.

In terms of price impacts, a full analysis is beyond the scope of this assessment. But the consumer price of electricity did increase by an average of 70 per cent between 2010 and 2016 (Ontario Energy Board 2016) and several commentators found that the over-generous feed-in tariff contracts were a significant factor in that increase (Auditor-General of Ontario 2015; Ontario Society of Professional Engineers 2016). Large-scale renewable procurement in Ontario has now gone to the reverse auction system successfully used by other jurisdictions, whereby concessions for defined blocks of power are awarded to the lowest qualified bidder. In a round of bids completed in March 2016, costs had fallen dramatically from what was initially paid out under the feed-in tariff regime: the average successful bid price for wind power projects was US$ 0.066/kWh, and the equivalent figure for solar was US$ 0.121/kWh (CleanTech Canada 2016).

In terms of jobs created, the Association of Power Producers of Ontario (APPrO 2015) estimates that between 2008 and 2014 wind power in Ontario created 88,842 jobs, if indirect effects are counted. The corresponding figure for solar power was 91,972 jobs and the biofuels figure was estimated at 21,378. These figures need to be viewed with caution, both because of the uncertain nature of the multiplier used to derive indirect impacts and because they are not net figures. They tell us how many jobs were created in the renewable energy sector, but not how many were lost in other sectors due to the direct effects of the phase out and the indirect effects of any higher electricity prices directly attributable to renewables. APPrO (2015) argues this latter effect is small.

In terms of the programme's success at fostering domestic capacity in the renewables sector–a key question–the available evidence is entirely anecdotal. The March 2016 large-scale auction awarded projects to a number of Canadian firms including those with headquarters in Ontario, partnerships with Ontario firms, and Ontario-based subsidiaries of multinationals (Blackwell 2016). This outcome is despite the fact that local content requirements were dropped from the programme in 2013 as a result of a challenge under World Trade Organization rules. The Samsung consortium built the contracted four manufacturing facilities in Ontario, in partnership with other multinationals–such as CS Wind, Siemens, SMA Solar–and some Canadian firms. Canadian Solar, founded in Canada in 2001, was the world's second largest solar company by MW shipped in 2015, operating in 18 countries with over 8,000 employees (Canadian Solar 2016). In 2014, Northland Power, an Ontario company that started in forestry, successfully completed the biggest non-hydro renewable energy financing deal in history—a US$ 5.8 billion agreement to build a 600 MW offshore wind farm in the Netherlands in collaboration with Siemens AG and two Dutch firms (McCarthy 2014). This sort of anecdotal evidence is indicative, but it is not conclusive, and further research is needed to assess the success of Ontario's drive to build domestic capacity in renewable energy technologies.

4. OPTIONS FOR POLICYMAKERS

In undertaking green industrial policy, policymakers have a wealth of experiences for guidance on what works and what does not. As discussed in this volume, the experience of traditional industrial policy holds many helpful lessons, even though green industrial policy is distinct in some respects, facing its own unique challenges and advantages (Altenburg and Rodrik 2017, this volume). Disruptive green industrial policy is similarly able to draw on decades of rich experience. But, as noted above, there are a few elements of this type of industrial policy that set it apart. In this section we explore the questions that arise about disruptive green industrial policy as distinct from other forms of green industrial policy:

- To what extent is it necessary to actively phase in the good while phasing out the bad, by pursuing a hard disruptive green industrial policy approach?
- How do states choose those sectors they want to phase out? This is akin to the traditional and difficult industrial policy challenge of picking winners.
- How should states go about the potentially painful process of phase out?

4.1. MUST WE ALSO PHASE IN THE GOOD?

Can a phase out or restriction alone, without an accompanying effort to foster replacement sectors, constitute green industrial policy? If there is an obvious substitute sector—for example, renewables for fossil fuels, electric vehicles for internal combustion engine vehicles–then a lack of proactive measures to develop the substitute domestically may simply mean that the goods will be imported. There is nothing inherently wrong with such a scenario; indeed, the prerequisites for successful industrial policy are demanding, and smaller and developing economies in particular must consider whether it makes sense to strive for domestic capacity in sectors where the conditions may not be favourable (Altenburg 2011). The point is, though, once a country has made the difficult decision to engage in disruptive green industrial policy, it should probably engage in positive measures to ensure that the resulting transition has the desired results. In doing so, particularly if the measures employed are closer to the hard end of the spectrum, policymakers should respect good practice for green industrial policy (Altenburg and Rodrik 2017, this volume).

If there is not an obvious successor sector, the desire may be simply to remove undesirable activities as part of a move to green the economy, in the expectation that whatever activity flourishes in the newly opened economic space will likely be less environmentally harmful than the phased out activity. This strategy has the disadvantage of potential unanticipated results, such as the rush to coal that followed Germany's phase out of nuclear power (Pahle 2010). But a more fundamental problem is public support: removing a sector that provides employment and contributes to conventional GDP is unpopular, no matter what the environmental benefits. There is some political value in being able to point to the promise of replacement green jobs, as in the case of Ontario.

Finally, while the phase out of a competing sector may offer powerful price signals for new green entrepreneurs, price signals alone are not likely to bring about the kind of fundamental and timely technological development, innovation and commercialisation needed to address the pressing environmental issues ahead (Hallegatte et al. 2013). Bazilian and Rentschler (2016) point to a number of non-price barriers, such as information, capacity and financial constraints, that may thwart results without complementary measures such as infrastructure investments, training and capacity building, and support for energy efficiency and innovation. Lütkenhorst et al. (2014:15) argue that:

"The introduction of environmentally sustainable technologies at the requisite scale and speed involves the breaking up of entrenched development paths…This massive challenge of societal adjustment coupled with the exceeding urgency of action thus requires more than simply getting the prices right…[T]he key task is to create incentives that push forward the development, testing, deployment and upscaling of sustainable technologies. This in turn presupposes the combination of smartly designed subsidies…with incentives to encourage and steer R&D efforts in the desired direction as well as investments into dedicated infrastructure and multi-stakeholder partnerships".

Ultimately, while disruptive policy is critically important in freeing the space for desirable forms of economic activity, it is not sufficient to ensure that those reforms maximise their potential to actually foster those activities, particularly given the urgency of the need for change. For that, complementary policies are needed to help phase in the sectors that will succeed those being phased out (Never and Kemp 2017, this volume).

4.2. CHOOSING THE SECTORS TO PHASE OUT AND TO PHASE IN

One of the traditional criticisms of industrial policy–and in particular hard policies–is that governments are not well placed to pick winners and losers (Pack and Saggi 2006). The losers in this sense are those sectors that do not receive support. Choosing who deserves support is indeed a difficult decision, ideally informed by knowledge of latent comparative advantage–knowledge that may not even be discovered yet by the firms themselves (Rodrik 2004).

The choice of sectors to target for phase out, via disruptive green industrial policy, is much more straightforward. While the choice in each country will depend critically on the context—resource base, sectoral mix, sectoral environmental performance, industrial capabilities, fiscal and macroeconomic context, socio-economic profile, and so on—policymakers in each case can nonetheless be guided by a few common principles:

- The sector for phase out should generate significant environmental damage, with poor opportunities for improvement. The first point is obvious, but the second is critical. If there are viable prospects for reducing the environmental damage caused by a sector, then producer states might choose to invest in developing that potential, avoiding the costs inherent in any radical transformation and perhaps benefiting from first mover status in the new innovative and relatively green space. This decision may come down to a comparison of the environmental consequences of the potential substitute sector relative to those that could realistically be achieved by greening the polluting sector at similar cost. The classic example of this dynamic is clean coal versus renewables.
- The status quo should see the sector for phase out as receiving significant fiscal outlays, whether in terms of outright transfers or in terms of tax breaks. This would mean lower opportunity cost to the phase out or, put another way, reduced fiscal outlays. As noted above, fossil fuel extraction and consumption score well on this criterion.
- Candidates for phase out should have viable substitutes that are significantly environmentally superior.
- Ideally, the substitute sector would be a beneficial economic driver: once the phase out of the targeted sector and the phase in of the favoured substitute are complete, the economy will realign with stated national development objectives. That is, the exercise of restructuring should be well grounded in the broader context of the development objectives of the implementing state, helping to move toward some desired end. The new sector might involve a higher degree of added value, for example, in a country that aims to move away from extraction or production of commodities, or might provide good prospects for skilled employment and spin-off benefits.

Even after policymakers choose the sectors to target for phase out, as well as the sectors for phase in, they still need to decide to actively pursue domestic capacity in the substitute sector. The alternative is to foster growth in that sector without discriminating between foreign and domestic proponents. This is a fundamental industrial policy choice, and it demands a great deal of information, vision and capacity—which are not always available to the decision-makers.

Where policymakers do choose to promote domestic capacity in the substitute sector, then additional guidance is clearly in order beyond what is offered above—that is, guidance on how to phase in a sector, involving both the choice of sector and the manner of implementation. There is an extensive literature on this topic (Grossman 1990; Rodrik 2004; Pack and Saggi 2006; Harrison and Rodriguez-Clare 2010; Altenburg 2011; Hallegatte et al. 2013; UNCTAD 2016). Never and Kemp (2017, this volume) provide lessons for the phase in of green technologies.

In the course of choosing sectors to benefit, green industrial policy faces a challenge that may be less relevant to traditional industrial policy: given the objective to achieve environmental improvement, it becomes necessary to add an environmental filter to the criteria used in picking winners. It could be argued that a proper conduct of industrial policy would already include such a criterion, but in any case it certainly needs to be part of the choice of sectors to promote in the context of green industrial policy. All forms of economic activity have some environmental effects, so while substitute sectors may leave us better off for having replaced target sectors, they themselves will also have environmental impacts, and these need to be understood as a prerequisite to commitments to sectoral promotion. The classic example of this dynamic is the push to promote bio-fuels as substitutes for gasoline and diesel in transport; there is a growing consensus that the environmental impacts of this particular substitute sector can be significant (Delucchi 2006; Runge and Senauer 2007; Searchinger et al. 2011).

4.3. HOW TO PHASE OUT?

Deliberately phasing out a sector is fraught with difficulties, particularly if it is entrenched and provides a significant contribution to the national or regional economy. The case studies of Jordan and Morocco demonstrate that reform is difficult–in both cases it had been unsuccessfully tried before–but possible. China has a command economy that makes it easier to phase out targeted sectors, but even there, compliance at the local level is a challenge. Ontario was fortunate in that it has no domestic coal production, but the restructuring was nonetheless a major effort, is still underway, and produces a case study in the political science of green economic transition (Harris et al. 2015). The programme faced significant opposition on the grounds that it would increase electricity prices and stymie economic growth, and that it constituted inefficient environmental policy (McKitrick 2013). The promise of new jobs from the promoted renewable energy sectors was critical in garnering public acceptance.

The process of adjustment in the face of disruption, however urgent and necessary, should respect the principles of the International Labour Organization's principle of Just Transition (ILO 2010). According to this principle, the need to respond to climate change is paramount and urgent; however, the process of transition that results needs to be planned with full understanding of, and accommodation for, the massive consequences for industries, jobs and workers. This is not only a moral stance, it is also pragmatic: Without the consensus that derives from a just transition, necessary reforms will not be politically viable.

These are not challenges typically faced in the exercise of traditional industrial policy that seeks to build up new sectors but not to directly disrupt existing ones. But overcoming them will be paramount to successful disruptive green industrial policy. Public support for disruption is crucial, especially if the phase out involves conflicts with powerful vested interests. There are a number of key elements to achieving necessary buy-in:

- **Public education about the nature and magnitude of the problem and the benefits of the planned reform:**

People need to be convinced that the status quo is unsustainable, undesirable, and that the plan will work. This was a key element in the fossil fuel subsidy reform processes of Jordan and Morocco, as well as many others (IMF 2013a; IMF 2013b; Vagliasindi 2012).

- **Compensation for vulnerable affected populations including under-represented groups in society such as women and youth:**

The International Monetary Fund (2013b) describes the success of Indonesia at fossil fuel subsidy reform in 2005—after multiple unsuccessful attempts dating back to 1997—as due in large part to well-communicated social spending with the resulting savings, including on unconditional cash transfers and health insurance for the poor, and assistance in fuel switching away from subsidised kerosene for cooking. A number of countries have also used a direct cash transfer system to ensure that the most vulnerable would not be negatively affected (IMF 2013b). When the primary consequence is job loss, the response might be training, relocation assistance and a strong social safety net. The precise form of the compensation scheme will vary with national circumstances, but the principle of 'low net harm' is important, and central to a just transition. Whether the shift takes the form of removing subsidies or levying charges, a portion of the resulting saving/revenue can be used to support this sort of compensation.

- **The promise of prosperity:**

If hard green industrial policy is being pursued, as in Ontario, governments can hold out the prospect of short-term pain from adjustment balanced off against long-term gain, typically in the form of jobs, from the advent of new green economic activity. The spending to support such measures achieves both the goal of cushioning adjustment and the goal of promoting green substitute sectors.

Support from the affected business community may also be vital to the success of the programme. It is important to identify who will lose in the reform process, and to plan ways to minimise the loss as much as possible, consistent with achieving the objectives of the programme.

- **Impacts on the business community can be softened by:**
  - Consultation with the affected sectors well in advance of the policies, to garner input relevant to their final shaping:

    This process may reveal ways to revise draft policies that reduce damage

  - Transparent and timely announcement of policies and timelines, giving some measure of stability and predictability:

    This allows for investments to be made with some certainty about future conditions.

  - Gradual reform:

    The more gradual the disruptive process, the less likelihood there is of stranded assets among the affected sectors, reducing the opposition. A balance is needed here, though, such that the speed of the process is appropriate to the urgency of the environmental problems addressed.

  - Support for affected non-targeted firms:

    Those firms from outside the target sector that are threatened might be helped by measures to boost competitiveness, including via measures to increase energy efficiency and reduce waste. This support can be funded by a portion of the savings or revenue generated by the phase out policies, whether they come in the form of subsidy removal or charges.

4. CONCLUSIONS

Disruptive green industrial policy poses several challenges that are not as salient for policymakers engaging in conventional green industrial policy. It forces governments to pick specific losers–firms and sectors that they wish to see restricted or phased out. Choosing those targets is a matter of assessing those sectors contributing most to environmental damage, for which there is an obvious viable green substitute. If the target sector currently receives subsidies, so much the better: the shift can be financed in part by the savings. Ideally, substitute sectors align well with nationally enunciated development priorities and fit well with domestic capabilities.

The most difficult aspect of disruptive green industrial policy is orchestrating a just transition, as illustrated by the chequered experience to date with one form, fossil fuel subsidy reform. The sectors responsible for most environmental damage tend to be those with significant capital investment and strong linkages throughout national economies in production and associated supporting activities. The transition away from such sectors, while necessary, will entail some level of stranded assets, obsolete infrastructure, direct and indirect job losses, and the attendant political battles against those negatively affected. Impact assessment of the effects on the environment, the industry and the economy at large–as well as social consequences for women and youth and other marginalized populations and whether or not gender gaps are further perpetuated by the proposed policy–should occur at every step of the transition. If the transition is not well managed, the desired disruption can be stymied or significantly delayed by popular opposition.

Fortunately, successful models are available, and some were discussed here. From them, it can be seen that it is crucial to get public buy-in, through extensive consultation and transparency combined with well-defined gradual timelines for change, and extensive efforts to ensure that there is support for those that might be negatively affected. Private sector buy-in is also key. Here again the process is important, with a need for consultation, transparency and well-planned gradual efforts. Support can be offered to non-targeted firms that may be negatively affected. For both the public and the business community, it might help to be able to point to future growth created by new green domestic firms.

Not all disruptive green industrial policy will actually make efforts to foster domestic expertise in the sectors that arise from the disruption. Each country will need to identify appropriate policies on a spectrum that runs from soft efforts—restricting or phasing out sectors with no efforts to steer the resulting emergence of green substitutes—to hard efforts: restricting or phasing out sectors with specific green substitutes in mind, and fostering the growth of domestic players in those substitute sectors. For some countries, particularly those without the requisite technical and fiscal capacity, hard disruptive green industrial policy may simply be infeasible. In this respect, disruptive green industrial policy does not differ from green industrial policy, or indeed from industrial policy.

Where it is feasible, however, striving to phase in substitutes for those sectors being targeted will offer greater potential to achieve the desired results of the transition. Simply getting the prices right, as China did by revoking value added tax refunds to undesirable sectors, may fail to address a host of other obstacles to transition, and for these a suite of complementary measures may be needed. In fact, China implemented such policies, setting targets for renewable energy penetration, providing finance, and investing in education and research and development to foster cleaner high value added production (Altenburg et al. 2017, this volume).

The speed and scale of the transition needed to combat climate change, arguably humanity's most pressing global environmental problem, demand a combination of phase out measures and phase in measures where it is feasible, even if our experience with industrial policy tells us that not all efforts to foster domestic capacity will succeed. In that sense, disruptive green industrial policy should be seen as a crucially important complement to other sorts of green industrial policy efforts, disrupting the status quo to create the space within which new green sectors can emerge.

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CHAPTER 6

DEVELOPING GREEN TECHNOLOGIES AND PHASING THEM IN

Babette Never, René Kemp

1. INTRODUCTION[12]

The development and phase-in of green technologies present complex challenges for industrialised and developing countries alike. First, neither international nor domestic market prices reflect the environmental externalities that come with conventional, non-green technology choices. Therefore, producers and consumers do not receive a cost-based incentive from the market to shift towards green technologies. Second, other market failures such as inadequate information on products and amortization periods, uncertainty about benefits, unclear incentives or behavioural barriers impede investments in green technologies. As a consequence of those market failures, product development and consumer preferences are focused on non-green technologies. Third, green technologies are disadvantaged by the continuous investment in and habitual use of polluting technologies that reinforce the lock-in of socio-technical systems (Kemp 1994; Unruh 2000, 2002).

Lock-in means that existing rules, organizational structures, sunk costs and actors' interests as well as knowledge and skill accumulation combine to stabilize an entrenched paradigm (Geels 2004; Kemp 1994). This is reinforced by regulating agencies that promote well-known and non-risky technologies, by economies of scale of incumbent versus emerging products and by network effects such as the interdependency of technologies, infrastructure and industries growing over time (Unruh 2002). The development and implementation of alternative technologies and systems thus face serious problems, in the form of opposition from current beneficiaries and of short-term costs weighed against undetermined long-term benefits.

These obstacles particularly challenge radical systemic changes, those requiring shifts in institutions and long-term development periods. The new techniques and technologies initially produce low payoffs because they have not yet benefited from the dynamic scale and learning effects that result in cost reductions per unit of output and incremental improvements (Kemp 1994). Moreover, they tend to be especially challenging in developing countries where policymakers have limited financial, institutional and professional resources and less experience with state-driven technology development and phase-in. While lock-in effects may be weak in some developing countries where techno-institutional development is just beginning, market failures may be more pronounced due to stronger information asymmetries and cost barriers.

In this chapter, the goal is to identify concrete options that governments in developing countries can usefully and realistically do to phase in green technologies. Factors for success and steps to manage transitional change are outlined and it is argued that, given the various market failures and lock-in effects, a deliberate process for phasing in green technologies is required in most cases. Longer time-spans, mapped-out policy steps and well-designed cooperation mechanisms among stakeholders need consideration. Uncertainty has to be overcome. Furthermore, policies that ignore the heavily vested interests in existing technologies and systems are unlikely to work. The importance of these various elements is illustrated by the cases discussed and aligns with innovation system dynamics (Markard and Truffer 2008). They also align with political economy studies of industrial policy that emphasize the importance of rent management and the need of a competent bureaucracy able to deal with information asymmetries (Rodrik 2014; Altenburg and Engelmeier 2013; Schmitz et al. 2015).

Further, successful phase-in experiences in industrialised countries of Germany and the Netherlands and in emerging economies of China and India are presented. The selected countries all have specific phase-in programmes for green technologies but differ with regard to financial and institutional capacities; therefore, each country developed different policy approaches. This chapter outlines useful elements of a green transition approach for developing countries, with special attention to difficulties they may encounter. Transition management literature offers useful starting points as it discusses a variety of options for policymakers. The literature suggests that technology phase-in becomes possible through experimentation with different policy mechanisms, through the development and protection of specific technological niches or through a combination of both. Transition management for developing countries thus offers more flexible options to address market failures, lock-in and vested interests than traditional technology policy approaches that support a specific pre-defined technology only with research and development and other financial incentives.

12 A different version of this chapter has been published as 'Green transition, industrial policy, and economic development' (Kemp and Never 2017), which was based on the version of this chapter.

Phasing in green technologies in developing countries is less about discovering new technological niches and more about recognizing which existing opportunities coincide with development objectives and building on that advantage. Few developing countries can financially nurture industries from infancy to global maturity. For the purpose of this chapter, it is therefore useful to look at sectors with a fairly established set of technologies available on the global market that can be adapted to local requirements. Renewable energy, particularly solar photovoltaics, and energy efficiency were identified to be such sectors. Both are constrained by a variety of market failures, uncertainties and lock-in situations. Renewable energies have to be phased in against a strong lock-in of fossil fuel-based electricity and heating systems in most countries, and often prices are still not competitive with conventional grid-based electricity. Energy efficiency implementation suffers primarily from non-transparent and inadequate pricing—but also from information failures and behavioural barriers. Thus, both sectors require government intervention for successful phase-in.

The structure of the chapter is as follows: Section 2 explains the transition management approach by summarizing the relevant literature. It gives a brief overview of potentially relevant factors for managing transitions in developing countries. Section 3 suggests which of these factors have been important in existing phase-in processes. Five policy examples are presented: energy efficiency in buildings in Germany, industrial energy efficiency in China, energy efficiency in India, solar photovoltaics in India, and a broader transition management approach in the Netherlands comprising renewable energy and energy efficiency. In conclusion, section 4 specifies key elements of a green transition approach for developing countries by discussing the lessons from the five examples.

2. PHASING IN FROM A TRANSITION MANAGEMENT PERSPECTIVE

The transition management literature offers many starting points for overcoming market failure and lock-in and for dealing with uncertainty and vested interests. However, operationalisation in developing countries requires focus on particular factors. This section outlines prospective key elements for such an operationalisation by clarifying the goals, design principles and tools of transition management.

Transition management seeks to overcome a situation of lock-in and market failure by co-producing and coordinating policies step by step with clear targets and programmes for system innovation. Co-production of policies means support for both top-down and bottom-up ideas and processes. The goal is to accelerate a structural transformation of the whole economy or of important sectors by utilizing innovation opportunities and designing policies that foster private investment into those opportunities. Transition management relies on the development of a long-term vision with interim transition goals and pathways by involving relevant actors and incorporating experimental programmes and projects as well as mechanisms of policy learning (Loorbach 2010; Kemp et al. 2007). For developing countries, the complementary expansion of institutional capacities and technology-related skills is essential.

The development of strategic, long-term visions is a necessary starting point for government-driven phase-in processes. Participating stakeholders need to change existing goals and principles, instead of waiting for others to challenge old goals or present new ideas. The re-clarification of visions and lasting goals serves stakeholders' long-term anticipation of policy developments and thus gives certainty to investors, innovators and consumers. Visioning exercises provide the desired result of the transition—in this case, a renewable energy-driven economy. Once these desired results are agreed, determining the necessary interim goals and planning the policies needed to reach the interim goals can start.

The design of interim steps and goals does not require omniscience on the part of the government to pick winners, nor does it require that all mistakes must be avoided "What is needed instead is a set of mechanisms that recognises errors and revises policies accordingly" (Rodrik 2014: 472). Several tools for selecting innovation possibilities and models for nurturing them exist: a flexible portfolio of options, an open search process with business and research, or a prior identification of user needs to help select priority sectors and technologies. It is crucial to enable policy learning while countering vested interests through embedded autonomy (Evans 2012). Embedded autonomy is the engagement of government representatives in business networks to obtain relevant information and capabilities to formulate feasible economic goals without allowing political capture. Political capture here means more than corruption; powerful interest groups may attempt to divert policy measures away from government's intended goals to undermine the effectiveness of those measures (Lütkenhorst et al. 2014).

The operational part of transition management emphasizes two aspects: experimental programmes and projects and/or strategic niche management. Experimental programmes and projects can be used to test technological options, learn about user satisfaction, identify problems with a range of technical issues and create networks for cooperation (Kemp et al. 2007). The role of governments is to make sure that interesting experiments happen and that lessons get evaluated and disseminated. For promising technologies with possibilities for branching and cost-reduction, they may engage in strategic niche management, in case the market smothers any such developments. Strategic niche management involves the promotion of promising technological experiments through financial incentives, networking and supportive policies for scaling up in a way that protects the experiments from competitive pressure. Once these innovations have reached full market maturity and begun to diffuse widely, the supportive policies can be withdrawn (Kemp et al. 1998). To what extent strategic niche management presents a feasible option for developing countries depends on the functioning and capacities of local innovation systems. In both experimental programmes and strategic niche management, starting small and scaling up successful programmes through iterative processes supports the process from a nurturing phase to an actual launch.

Policy learning is essential. The transition management approach acknowledges that a successful phase-in of green technologies requires a long time-span with several cycles of adjusting policies until full implementation of the desired outcome is reached. Explicit policy learning rounds are planned to evaluate which interim goals have been achieved; whether the process is dominated by certain actor groups and vested interests; and how regulations, procedures and goals need to be adjusted to match long-term and short-term concerns (Rotmans et al. 2001). Ideally, this leads to gradual changes that minimise social resistance.

The transition management approach has been criticised for its too-strong focus on technological, rather than broader societal, innovation; its emphasis on the policy design phase and its de-emphasis of political factors, as well as the role of societal actors in the implementation phase (Kemp et al. 2007). The disregard of political factors presents the most important caveat. The approach presupposes that policymakers and implementing agencies are technically capable and fully committed to increasing social welfare without being influenced by lobbying pressure, patronage, populism or party politics. In the real world, such conditions are the exception rather than the norm. Systemic transitions result from complex political bargaining processes among competing interest groups, while policymakers and implementers often pursue self-interests that mingle with their official mandates. Lobbyists will try to influence the policymaking process to gain personal benefits, and politicians as well as bureaucrats will strive for power resources and political support (Chang 1996). National politics are too often shaped by exclusive elite deals and patronage, which strongly deviate from the ideal-type of a state with an efficient, meritocratic and accountable bureaucracy.

These risks loom clearly in the management of systems transitions. Here, policymakers need to create special economic incentives, policy rents, to steer the economy towards a more desirable new state and withdraw incentives from undesirable activities such as polluting. Such rent management presupposes particularly capable and welfare-oriented governments that are immune to political capture (Khan 2004; Altenburg and Engelmeier 2013). Therefore, the risks of public or private interest groups distorting transition policies should not be underestimated.

Transition management does not prescribe one particular path for phasing in green technologies. Instead it offers a framework for exploiting green development opportunities in a forward-looking, adaptive way. Environmental protection benefits can be combined with economic benefits in such a green transitions approach. The next sections analyse different successful cases to identify both common and unique elements of phasing in from a transition management perspective that could be particularly important for developing countries. Exploring the political economy behind each of these practical examples is beyond the scope of this chapter. Interestingly, however, the cases show that governments of industrialised and emerging economies alike have been able to manage transitions effectively.

3. HOW TO INSTIGATE AND MANAGE THE TRANSITION? PRACTICAL EXAMPLES

The following five examples of successful phase-in programmes will all be introduced by a brief explanation why such a programme was required, followed by a description of what has been done. Then the programme's effects will be discussed in the context of industrial policy. Finally, key elements of each approach will be summarized. The German, Chinese and Indian cases are all sector-specific examples. The case study of the Netherlands showcases a more systemic approach on a comprehensive level, encompassing the whole energy sector. For developing countries, the choice between a more selective or systemic approach depends on the state of the sector, such as market and readiness to innovate; number and interest of actors; technologies already available; the linkages between actors and market segments and analysis of which technologies can be locally adapted in line with development objectives. More developed market segments with potential for strong linkages to others, such as solar photovoltaic modules, seem to work best through a systemic approach.

3.1. ENERGY EFFICIENCY IN BUILDINGS IN GERMANY

In Germany, buildings account for around 35 per cent of final energy consumption that includes heating, ventilation and warm water provision (NAPE 2014). Roughly 75 per cent of residential buildings are older than 30 years and require improved heating and insulation systems. In spite of existing regulations, energy efficiency in buildings is difficult to achieve, especially in older buildings that require refurbishment. The following market barriers exist in industrialised and developing countries alike, calling for governmental intervention (Liu et al. 2010):

- When constructing a new building, future monthly energy costs for cooling, lighting and heating make up a small share of the cost calculations. Energy subsidies may reinforce this disincentive for energy efficiency investments. Owners may be unwilling to modernise buildings because they do not want to write off investments. Both situations distort cost-benefit perceptions.
- Building owners may have other interests than tenants, creating split incentives among stakeholders.
- The building sector's many stakeholders lack coordination.
- Builders, owners and tenants lack information and knowledge regarding a building's energy performance.
- The variety of technologies and the measurement challenges add to the complexity of delivering more efficient buildings.

The German government's approach to increasing energy efficiency in both old and new buildings involves measures around three pillars: regulation, mainly command-and-control instruments; financial incentives; and information to build trust. The three pillars were designed to complement and mutually strengthen each other (Schimschar 2013; Schröder et al. 2011). Moreover, the different measures are linked to renewable energy objectives to form a coherent energy policy package. By way of these measures, by 2050 primary energy consumption in buildings should be only 20 per cent of consumption in 2008.

Germany's first thermal insulation regulation was developed early in 1977, but political momentum towards implementing mandatory standard setting only gained traction in the 1990s. Currently, the energy saving ordinance, called Energieeinsparverordnung (EnEV) and comprised of the German building code and the act on the promotion of renewable energies in the heat sector, provides the regulatory framework. The German energy saving ordinance was introduced in 2002, in line with that year's European Union directive on the energy performance of buildings, and was revised and tightened in 2007, 2009 and 2013. The EnEV 2013 is the first regulation that outlines a stepwise tightening of construction law to a carbon neutral standard by 2021 (El-Shagi et al. 2014). Standards are thus incrementally introduced and tightened over time.

Financial incentives to comply with regulations and voluntary mechanisms are provided in the form of subsidy programmes for the refurbishment and construction of new buildings by the public bank, Kreditanstalt für Wiederaufbau (KfW), and for heating with renewable energies, Marktanreizprogramm zur Nutzung erneuerbarer Energien im Wärmemarkt (MAP). The government's 2004 CO_2 Reduction Programme includes two subsidised loan schemes: the KfW programme for energy efficient refurbishment and the KfW programme for energy efficient new buildings. Grants and loans are staggered according to the degree of energy efficiency:

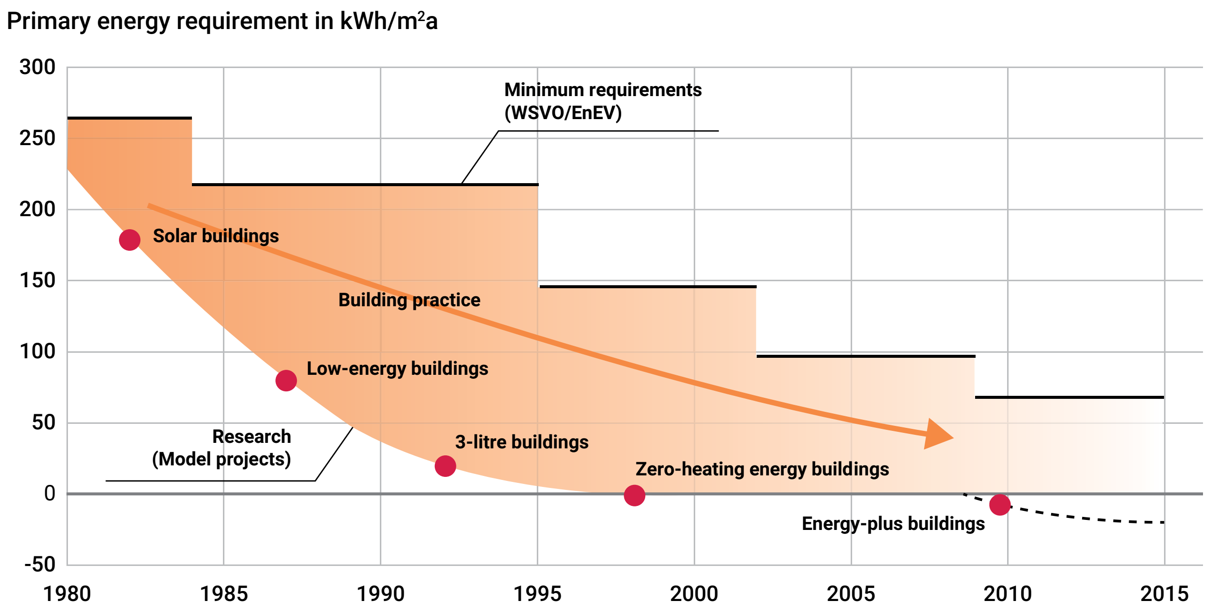
the more energy efficient the building is, the higher the grant and the more favourable the repayment conditions for loans. This approach covers the whole range of technically feasible options on the market and it is revised regularly to increase energy efficiency. Preferential loans with low interest rates for energy efficiency can be combined with loans for a new heating system based on renewable energies.

Information-based programmes, such as the mandatory energy performance certificate for buildings and the targeted promotion of jobs and expertise related to energy efficiency, complement the policy package. Various information and trust-building measures for homeowners, tenants, experts and the construction industry support knowledge exchange and provide security for stakeholders in the market.

The incremental introduction of standards presents a particularly interesting element in the German three-pillar approach. It provides the market with both clear signals and sufficient time to adjust. New standards are tested in pilot projects to identify the optimal technology available on the market and revised every few years. While the regulatory framework is being expanded the German Energy Agency, called Deutsche Energie-Agentur (DENA), and KfW promote model and experimental projects and commission research to accompany and evaluate running programmes. For example, DENA developed and tested the standards for Low-Energy buildings on 400 individual projects (Figure 6.1). KfW subsequently adopted these standards to support an additional 5,000 prototype buildings (Schröder et al. 2011: 35).

The German energy efficient building programme has had positive effects on energy consumption, regional value chains and investment dynamics in the sector. The incremental introduction and tightening of regulations accompanied by research and model projects have led to substantial reductions in primary energy consumption over time (Figure 6.1).

Figure 6.1: Long-term phase-in of building standards



Source: National Energy Efficiency Action Plan Germany (2014).

The incremental tightening of regulatory requirements pushes energy efficient building practices towards greater efficiency. The continuous development and testing of most efficient buildings in model projects, such as solar buildings and zero-heating buildings, create a pull-effect on the market. The actual building practice lies between the respective regulation at the time and the most efficient technologies possible, becoming more energy efficient over time.

In 2011, the energy efficient refurbishment of existing buildings affected regional value chain by EUR 14 billion and generated about 287,000 full time jobs (Weiß et al. 2014). Since 2006, 3.7 million dwellings could be refurbished or newly built in an energy efficient manner with an overall investment volume of EUR 182 billion. On average, between 2006 and 2011 every public Euro invested in KfW subsidy programmes generated EUR 10–12 of private investment (Weiß et al. 2014).

Additionally, a strong indirect effect of regulation on innovation can be witnessed. Investors in the high-end housing market segment strongly react to a narrowing technology advantage compared to adopters in the low-quality market, even if their own performance is not threatened by regulation in the near future (El-Shagi et al. 2014). These results confirm a weak form of the Porter Hypothesis on regulation and innovation–that environmental regulation stimulates innovation and thus increases the competitiveness of firms and the economy (Ambec 2017, this volume).

Overall, the continuous revisions of regulation and incentives, as well as the combination of different types of measures in a policy package, explain the success of the German programme thus far. A high degree of collaboration among actors in the policy process and the integration of experimental pilot projects with accompanying research that fostered feedback and learning cycles, as well as the gradual tightening of requirements in all fields, supported the achievements greatly. Finally, energy efficiency measures were explicitly coupled with the promotion of renewable energy usage in buildings.

3.2. INDUSTRIAL ENERGY EFFICIENCY IN CHINA

A decade ago, the Chinese industry appeared to be locked into an unsustainable, fossil fuel-based path. Industrial energy consumption increased significantly in China: from 34 per cent in 1990 to approximately 70 per cent of total national energy consumption in 2009. This decreased to 50 per cent in 2015, but 65 per cent of all electricity was still produced from coal in 2016 (China Energy Portal 2017). Since energy prices for industry are negotiated regionally, the market does not send a consistent countrywide signal to invest in energy efficiency. Before the Chinese government started its industrial energy efficiency programmes, companies hardly invested in energy efficiency. The central government does provide targets and guidelines to local governments, but keeps policy goals broad enough to allow for local interest alignment and bundling of policies and incentives (Harrison and Kostka 2014).

Since the 1980s, China had been monitoring energy use in industry. In 1995, the government published a guideline for energy management in industry, indicating to companies that future regulation was to come. Concrete interest in energy management systems in industry started to rise in the early 2000s after it became clear that rapidly increasing energy demand had to be brought under control (Zhou et al. 2010). Following the introduction of the Energy Conservation Law in 2001, the government developed a comprehensive package of mandatory and voluntary policies and measures aimed at advancing energy efficiency and energy saving. The Medium and Long Term Energy Conservation Plan was published in 2004. In the 11th Five Year Plan (2006–2010), command-and-control regulations were combined with taxes and subsidies—sticks, carrots, sermons and prohibitions (Yang et al. 2015).

Sticks: The Differential Electricity Pricing Policy for industries consists of four categories with different surcharges that increase with consumption. More efficient enterprises thus pay less. Between 2004 and 2010, these types of taxations were subsequently increased. However, initial charges were found to be inefficient in terms of increasing energy efficiency investments. This was due to heterogeneous, counteracting local policies and fluctuating selling prices and other production costs (Yang et al. 2015). To phase-out inefficient enterprises, the surcharge in this category was increased by a factor of four over time.

Carrots: Companies can receive a reward of 250 Yuan per tonne of coal equivalent saved through technical upgrading and engineering projects or the Ten Key Energy Saving Projects. A number of research and development support strategies for different business sectors as well as financial compensation for technical retrofitting and the phasing-out of small and inefficient industrial plants exist (Yang et al. 2015).

Sermons: The Top 1000 energy savings agreement between key industry and government was voluntary when first introduced in 2006 and gradually extended to provincial and local levels (Yang et al. 2015). In 2012, the programme became mandatory and was expanded to the Top 10,000. It requires companies to annually send their energy use statistics to government and to meet national and international standards. The Top 10,000 programme and its combination with energy management systems helped to raise awareness among provincial authorities and top-level management. But the implementation of it is impeded by a lack of understanding in non-Top 1000/10,000 companies, as well as a lack of funding and adoptable technical means (Goldberg et al 2011; Li et al. 2014). The proper adoption of energy management systems–either the national standard or ISO 50001–can actually make it easier for companies to comply with regulations and monitoring schemes. The electricity saved may then qualify the business for a different electricity price category.

Prohibitions: The 2006 Plan on Energy Conservation and Emissions Reductions sets targets for the closure and phase-out of small and inefficient production facilities. Several provincial and local governments, however, prioritise local economic development and jobs. They protect local factories from closure or let them operate unofficially, thus opposing national policies (Yang et al. 2015).

China's approach to industrial energy efficiency did produce the envisioned reduction in energy intensity of 20 per cent by 2010, but progress since has been rather slow. The implementation of national energy policies relies on creative bundling of interests, incentives and policies by local governments and administration to minimise opposition of local players (Harrison and Kostka 2014). The government is struggling to achieve structural change that actually replaces less energy-efficient firms and technologies with more efficient ones across all sectors during the 12th 5-year period of 2011 to 2015 (Ke et al. 2012). Official documents state that 340 million tonnes of coal equivalent have been saved under the Ten Key Projects programme until 2010.[13] A gradual, cautious introduction of a carbon trading system is now envisioned to complement existing measures. The diffusion of these measures to medium and small energy intensive companies presents a challenge in the next stage of China's phase-in process.

Concerning industrial policy effects on the supply side, the market for energy efficiency consultants and energy service companies has been developing since 2006. From 2010 to 2015, this market grew by 31.9 per cent annually, employing 654,000 people in approximately 2,600 companies by 2015 (IbisWorld 2015). In spite of these numbers, energy efficiency consultants and energy service companies have been criticised for not working effectively enough due to imperfect business models, asymmetric information, high transaction costs, lack of ability to build a relation of trust to customers and lack of skills especially in new energy industry services (Kostka and Shin 2013). Energy auditing capabilities vary greatly throughout the country. While the market is developing well, it is far from having reached maturity and use of its full potential across the whole country.

Overall, the current Chinese policy package and path for phase-in are characterized by a short period of voluntary agreements and incentives, followed by comprehensive mandatory requirements for large industry. This led to an impressive achievement of energy consumption reductions in a rather short time span, while also establishing the topic firmly on the political agenda and creating local jobs. The shift from voluntary to mandatory measures is based on an assessment of the actual capabilities of leading industry to reduce energy intensity. Strategies are adjusted over time if they do not bring the desired results: experimentation, policy learning and strategic space for local interest alignment characterize the phase-in process. Fiscal incentives are part of the broader energy efficiency policy package, but are not yet interlinked with other mechanisms to maximise the effect. The existing political economy challenges between central and local governance levels indicate that awareness, capabilities and interests of different actors require projected considerations in the planning of green technology phase-in. This is particularly important for developing countries facing similar challenges.

3.3. ENERGY EFFICIENT LABELLING OF APPLIANCES IN INDIA

In India, residential energy demand accounts for 45 per cent of the country's primary energy consumption, 80 per cent of which can be ascribed to only five appliances: ceiling fans, TVs, lighting, refrigerators and air-conditioners. The consumer appliance market grew at an annual average of 13 per cent between 2003 and 2013, increasing overall energy demand (Jairaj et al. 2016). Inefficient appliances have a lower price on the market and consumers often lack the information that more energy efficient appliances save more on their electricity bill so that the higher purchase price can thus be amortized quickly. Manufacturers had no incentive to invest in the development of more efficient, higher priced goods that they feared consumers would not buy (Chaudhary et al. 2012). These market failures needed to be overcome to use India's projected potential to save up to 240 TWh of electricity through energy efficiency standards by 2030 (Letschert 2014). India has adopted a 'market-plus approach' (Harrison and Kostka 2014). The rules of the market are defined by the state, but the limited capacity of the state to ensure widespread implementation was acknowledged from the start, recognizing that different actor groups with diverging interests needed to be brought on common ground (Harrison and Kostka 2014).

In 2001, the government set up the Bureau of Energy Efficiency (BEE) with the mandate to develop an energy efficiency programme for

13 Ke and co-authors (2012) doubt this figure. Due to measurement and calculation challenges, it is difficult to ascribe effects to specific programmes.

household appliances and lighting, buildings and industries, including standards and labelling. It had been clear to stakeholders for several years that a standard and labelling programme for appliances was due and it was introduced in 2006. In the planning and design phase, extensive consultations had been held with manufacturers, utilities, standardization bodies and other stakeholders. The programme consists of a star-rating scheme based on minimum energy performance standards set by BEE and represented by a range from 1 to 5 stars. Labels were voluntary at first, then made mandatory once labelled products reached 50 per cent of overall sales. Facilities for testing the appliances were developed to allow for independent testing and mandating government procurement at the highest star ratings created market pull (Chaudhary et al. 2012). BEE plans to ratchet up the performance standards for the stars over time in an attempt to promote product innovation.

In the initial phase of the programme, standards and labels were designed to encompass a majority of the market and to provide the clear message that standards would be ratcheted up. Extensive consumer outreach and information was provided to build up the labels as a brand. Manufacturers self-certified the products by adopting the approved testing procedure and were thus responsible for the accuracy of the labels. Due to understaffing, BEE outsourced the process of collection, verification and processing of self-certificates to a consulting firm (Jairaj et al. 2016). BEE carries out market assessments regularly to understand market penetration, but these are not publicly available, making it difficult to judge how much the diffusion of efficient products has advanced in each product category (Khandari 2011). Since BEE has been functioning as both the designer of programmes and facilitator to state governments and businesses at all levels, the reliance on outsourcing services and the development of an energy efficiency consultants and energy services market soon became inevitable. While this market is evolving, it is still largely located in Delhi, Mumbai and Pune (Harrison and Kostka 2014). Future challenges across India include the establishment of trusted client-energy service relationships as well as increasing the attention of public agencies to electricity price and expenditures. Co-benefits are the key argument for energy efficiency in India, thus bundling interests of diverging and possibly opposing stakeholders (Harrison and Kostka 2014).

By 2016, frost-free refrigerators, tubular fluorescent lamps, room air conditioners and distribution transformers had progressed to mandatory labelling, while 17 additional products were under the voluntary labelling scheme. In December 2012, the target of the standards and labelling programme had already been surpassed: 7,766 MW of new generation capacity addition were avoided, greatly surpassing the 3,000 MW estimated (BEE 2014). Market uptake for appliances with 4 and 5 star levels of efficiency has generally been slower than for medium-level appliances (Jairaj et al. 2016). While the initial phase of the programme had been highly participatory with a clear roadmap, the frequency of review and the intention to ratchet up current standards are not sufficiently clear to all manufacturers now. Consumer awareness programmes have achieved growing brand recognition of the star label, but the share of inefficient devices is still significantly higher than the one for higher star-labelled ones. The absence of a targeted communication plan limits the full outreach potential, for instance via civil society organizations (Jairaj et al. 2016). These factors currently retard the building of a broad societal acceptance of energy efficient appliances across all of India.

The factors responsible for the success of the programme thus far have been a detailed understanding of the local needs, the sector and institutional context as well as extensive consultations with a range of stakeholders (Chaudhary et al. 2012). The idea of embedded autonomy and communication worked well in this case. This ensured the buy-in of all relevant actors, including incumbents and innovators in the system. The gradual tightening of standards and labels in line with the roadmap initially provided to stakeholders was initially helpful, but needs to be improved so that the process is clear to all relevant stakeholders.

3.4. SOLAR PHOTOVOLTAICS IN INDIA

India has a high solar irradiation and sufficient amounts of open space in several of its states. There is a vast potential for both on and off-grid solar energy, offering both energy and socio-economic development opportunities. However, the energy system has been locked into fossil fuels with a strong local coal industry for a long time. The key dilemma was this: Converting solar irradiation into electric energy was much more expensive than the well-established technology of coal-fired power plants. It was clear that solar-based electricity would become much cheaper once it was produced at scale and that burning coal caused severe health problems related to air pollution, as well as global warming. However, the market did not provide any incentive for developing solar projects as long as electricity from coal was cheap and environmental externalities were not considered. Additionally, a lack of regulatory certainty discouraged investments in the sector.

The central government's solar photovoltaics programme sought to change this. It offered a policy package to develop solar energy technology into a viable and competitive alternative by shielding it from price competition with coal. As such, it can be understood as an example of strategic niche management, in the terms of transition management literature.

An interest in solar policies began to arise in the states of Gujarat and Rajasthan in the early 2000s. In 2008, the Jawaharlal Nehru National Solar Mission was announced as part of the National Action Plan on Climate Change. It provides a long-term vision with clear targets to be achieved in each of its phases. The Solar Mission's different phases include a comprehensive set of measures: preferential feed-in tariffs, renewable energy purchase obligations and certificates, tax incentives, preferential loan schemes, as well as local content requirements to support the build-up of national manufacturing capabilities. In terms of targeted innovation support, government institutions receive a 100 per cent, and the private sector a 50 per cent, research and development subsidy for advancements in solar energy (Sahoo 2016; Quitzow 2015). State-level incentive programmes complement the federal legislation.

The most interesting element of the Solar Mission is the reverse bidding approach that brought the required subsidies down at an unprecedented speed. The Government of India auctioned licenses for solar power projects asking the bidders to hand in proposals below a reference price of EUR 0.27/KWh that the government would guarantee for 25 years. In the first round, the government auctioned very small projects of just 5 MW. Already here, investors' engagement was overwhelming, and the lowest bidders offered to build such plants with a feed-in tariff of only EUR 0.11/KWh. In subsequent rounds, the government auctioned larger units and, from round to round, received lower bids. This way, the government managed to trigger an enormous growth of the solar energy market while at the same time bringing the price differential between conventional and solar energy down and greatly reducing the fiscal cost of the solar feed-in tariff (Altenburg and Engelmeier 2013). Since 2009, the start of the Solar Mission, India's installed solar capacity increased from virtually zero to 5,130 MW by January 2016. The solar energy market has been growing at an annual rate of more than 300 per cent in the last five years. In 2014, approximately 125,000 people were employed in the solar photovoltaics sector in India, both on and off-grid. At the same time, the tariff that the government has to guarantee for new solar projects has been reduced to below EUR 0.08/KWh on average in 2014 to 2015 (IRENA 2015)–not much more than the cost of a KWh from coal-fired power plants.

The Jawaharlal Nehru National Solar Mission was less successful with regard to another objective, namely to boost domestic photovoltaic cell and module manufacturing capabilities. To achieve this objective, a local content requirement was included in the solar energy incentive package. There are two types of photovoltaic cells: crystalline silicon and thin film. Before the Solar Mission, India already had a decent production of crystalline silicon cells that was mainly export-oriented. The local content requirement made local sourcing mandatory for crystalline silicon cells but not for thin film cells, which were not produced locally at all. Project developers then tried to avoid the mandatory local sourcing by almost exclusively offering projects on the basis of thin film technology (Johnson 2013). Therefore, a well-intentioned local content regulation resulted in a bias towards foreign thin film photovoltaic manufacturers rather than supporting the local crystalline silicon manufacturing industry (CEEW and NRDC 2012).

In a nutshell, the solar policy was highly successful in terms of phasing in solar power technologies from the beginning, but not necessarily for the promotion of local green industrial production. The policy design and implementation incorporate a good deal of experimentation and systematic learning. This is noteworthy. With regard to the reverse bidding approach, the government started with a small test run that helped to identify some loopholes in the bidding process that were eliminated in subsequent rounds. In fact, the specification of tenders was improved from one round to the next. Also, the government commissioned a systematic mid-term review to an independent organization. The report praised that the solar mission "follows a phased approach that allows the government to modify guidelines and policies based on the experiences gained and lessons learned in earlier phases" (CEEW and NRDC 2012). It also clearly identified the local content requirements as dysfunctional, and these were suspended for the next phases. Overall, the Indian government's sequential approach–with a clear roadmap, intermediate targets, packaging of different measures and experimental learning–has been hugely successful for phasing in solar photovoltaic energy.

3.5. TRANSITION MANAGEMENT IN THE NETHERLANDS

The Dutch transition management approach for sustainable energy is a systemic green industrial policy approach. Its goal is to stimulate new business in sustainable energy and to foster a broader energy transition. To develop such a systemic green industrial policy, the traditional divide between the Ministries of Economic Affairs and the Ministry of Environment had to be overcome. This happened in a deliberative process that resulted in the co-production of the transition management framework (Kemp and Rotmans 2009). It envisioned the set-up of seven transition platforms, the development of a transition action plan and different transition paths explicitly entailing experimentation as well as institution, capability and network building.

The transition approach officially started in 2002 with the project implementation transition management of the Ministry of Economic Affairs. In 2004 to 2005, the energy transition process gained speed through the establishment of four transition platforms: new gas, green resources, chain efficiency and sustainable mobility. In these platforms individuals from the private and the public sector, academia and civil society come together to develop a common ambition for particular areas, to develop pathways and to identify useful transition experiments. In 2006, two additional platforms were established, sustainable electricity supply and built environment. The transition path of energy producing greenhouses became a platform of its own in 2008.

The suggestions of the transition platforms lead to a transition action plan, containing the following goals:

- minus 50 per cent CO_2 in 2050 in a growing economy
- an increase in the rate of energy saving to 1.5–2 per cent a year
- the energy system getting progressively more sustainable
- the creation of new business.

Following the work of the transition platforms, 31 transition paths have been explored through research and innovation experiments. These included, for example, biomass for electricity, clean fossil fuel, micro cogeneration and energy-producing agricultural greenhouses. The government acts as a process manager, dealing with issues of collective orientation and interdepartmental coordination. It also has a responsibility to undertake strategic experiments and programmes for system innovation.

The transition approach went beyond technology support. The creation of capabilities, networks and institutions for transitional change through agenda-setting, new partnerships and instruments was equally important, leading to actor coordination across national, state and local levels and cross-sectoral policy coordination. The Interdepartmental Project Directorate Energy Transition presents one group that had a central role in the process. It was set up in parallel to the transition platforms for this purpose. It plays an important role in taking initiatives, connecting and strengthening initiatives, evaluating existing policy and acting upon the policy advice from the *Regieorgaan*[14] and transition platforms, to stimulate interdepartmental coordination and to make the overall transition approach more coherent (VROM and EZ 2008, p. 10).

The front-runners desk, also created in 2004, presents a second, particularly interesting group (Table 6.1). It was set up to help companies solve problems innovatively and to help policy to become more innovation-friendly. Problems varied from difficulties with getting financial support from government or private finance to problems with getting permits. Between January 2004 and March 2006, 69 companies approached the desk to discuss problems. In 59 per cent of the cases, the problems were solved thanks to the intervention of the desk, in 12 per cent of the cases the companies could not be helped, and in the remaining 29 per cent of cases the desk was still dealing with the issue at the time of the evaluation.

14 The Regieorgaan is a committee that is responsible for developing an overall vision for the Netherlands' energy supply and to formulate a strategic agenda based on inputs from the transition platforms. Its members are the chairs of the seven transition platforms and four independent experts.

Table 6.1: Overview of functions of front-runner desk for innovators and policy

Functions for innovators	Functions for policy
Obtain financial support from existing instruments	Make existing instruments more conducive for innovation
Get into contact with relevant agencies and government people	Improve policy coordination between ministries and within ministries
Overcoming legal problems and problems with permits	Stimulate case-sensitive implementation of existing and new policy
Widen their network and strengthen the organizational set up of the innovation trajectory	Stimulate policy development in areas of the innovation chain not well covered by policy
Business support and public relation help for the successful market introduction	Be serviceable to business in a case-sensitive way

Source: Weterings (2006).

In 2011, the transition management was officially abandoned as part of an overhaul of innovation policy by a minister for Economic Affairs who was pro-nuclear and pro-fossil fuels for economic reasons. Unofficially, however, it continued in the form of a green deal approach, support for a bio refinery plant and a EUR 50 million programme for zero-energy buildings. For electric mobility, an action plan with a budget of EUR 65 million was created (Van der Beeson et al. 2014). In 2013, a sustainable energy covenant was signed by employer organizations, worker organizations, the financial sector, nongovernmental organizations and the national government in which the parties agreed to invest and work towards in energy efficiency and renewable energy. It is an attempt to involve business and societal organizations in the energy transition.

The effects of transition management are difficult to pin down. The experiences with the front-runner desk are very positive and the business of electric mobility received a big boost. Between 2008 and 2013, the economic value of the e-mobility sector in the Netherlands showed a six-fold increase in gross value added: from EUR 20 million to 120 million by 2013. The number of jobs in this sector increased from 300 to 1,600 full-time equivalents. The effects of the covenant for sustainable energy are unclear as an evaluation is pending, but progress appears to be low, due to the weak instrumentation of the approach.

In summary, the transition management approach has many good elements, but also suffered from serious problems. Among the positive lessons are the societal agreement on transition targets, the built-in evaluations and learning mechanisms, the phased approach and the use of public-private partnerships in implementation. One problem was that the liberalisation of the energy markets worked against the energy transition project, leading to policy inconsistency. A second problem was the large influence of incumbents from the gas and oil sector in the platforms. The support of research and innovation in sustainable technologies has proved easier than the phase-out of non-sustainable technologies. The politics of this make this a difficult task for any country.

4. CONCLUSION: KEY ELEMENTS OF A GREEN TRANSITION APPROACH FOR DEVELOPING COUNTRIES

A green transition approach for developing countries explores options to manage the transition from the current to a green economy that reflect the complexity of societal transformations in the local context. To agree on different paths and to implement long-term objectives, intermediate steps as well as experimental public-private processes are useful. A green transition approach highlights the importance of open-ended collective learning processes, and it is actively concerned with capacity development at the level of government agencies, knowledge-diffusing institutes and business actors. Relying on embedded autonomy for the formulation and adaptation of policies presents a key to successful transition management. While this chapter focused on examples from solar photovoltaics and energy efficiency in China, Germany, India and the Netherlands, other green technologies may be as attractive for a broader green transition approach in a developing country. Regardless of the technology and policy field, seven key elements that increase the chances for successful phase-in over time, based on government support, could be identified.

First, pro-active planning on the part of government is required as an initial step. This includes the development of a long-term vision and a clear roadmap with interim goals and steps. Choices are informed by policy intelligence about barriers and the effectiveness of policy interventions.

Second, this vision and roadmap need to be communicated early and clearly to investors, innovators and other stakeholders to identify technologies and innovations and to prepare the producers and consumers. The inclusion of relevant stakeholders such as manufacturers, business associations and standardization bodies at an early development stage is advisable as embeddedness without political capture.

Third, the selection of options for support and the forms of support should be conducted carefully, with the help of independent experts. The challenge is to avoid wasteful subsidies and political capture by lobby groups. Auctions, competition among service providers and time-bound subsidy schemes help making support cost-effective.

Fourth, a sequential approach works well in the examples discussed here. This can take the form of gradual tightening of regulations and standards or the testing in pilot projects before supporting a broader scale-up.

Fifth, explicitly include policy learning in the phase-in process to achieve socially and economically acceptable and successful implementation. These processes are complex and programmes may turn out quite differently than planned. Current market and technology developments may also require adjustments over time. The Chinese and Indian cases have shown that allowing some policy space for strategic bundling of different stakeholder interests at local levels may be an important part of this policy learning.

Sixth, designing a policy package was helpful in many of the examples discussed here. This policy package can include policy-push and market-pull policies as well as research and development, institutional capacity, skill and job creation measures, such as building-up a consultancy and certification industry.

Seventh, adequate implementation control mechanisms need to be put in place. The building and financing of technology testing facilities and the evaluation of implementation schemes are as important as fostering consumer awareness for an energy efficiency label, for example.

These seven elements are features of transition management, boiled down and pinpointed for a green transition in developing countries. They present no guarantee for the successful development and phase-in of green technologies in each and every case. Other factors such as foreign direct investments or financial constraints may affect phase-in processes. Coupling phase-in with phase-out by simultaneously reducing support for non-sustainable technologies and increasing incentives and subsidies for green technologies is also important (Cosbey at al. 2017, this volume). The green transition approach outlined here gives starting points for policymakers in developing countries interested in possible roadmaps for phasing in green technologies.

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CHAPTER 7

PRICING ENVIRONMENTAL RESOURCES AND POLLUTANTS AND THE COMPETITIVENESS OF NATIONAL INDUSTRIES

Kai Schlegelmilch, Hans Eichel, Anna Pegels

1. INTRODUCTION

Pricing the use of environmental resources and the emission of pollutants is one of the best ways to signal environmental costs while leaving it to competitive market forces to find the best technological and organizational solutions. The main pricing instruments are cap-and-trade systems and environmental taxes. These market-based instruments use the main signal in a market economy, the price, to indicate the costs of an investment or consumption decision. Leaving out that signal would be missing a major opportunity–if not the major opportunity–to shift a market economy in the direction of a green economy that complies with long-term sustainability criteria.

Environmental taxes are a very crucial element of green industrial policy. Since these instruments are potentially so effective at redirecting investment, they may have strong negative effects on the competitiveness of polluting industries. On the positive side, they increase the competitiveness of industries that manufacture sustainably and offer efficient green technologies and services. As policymakers proceed with green industrial policy design and implementation, it is important that they anticipate these effects, while supporting green technologies and keeping the costs of adaptation manageable.

This chapter explores the various benefits and the rationale of environmental fiscal reform elements in more depth. It points out how the elements need to be designed, particularly in developing countries, to achieve the dual purpose of protecting the environment while spurring competitiveness, industrial development and jobs and offsetting potential negative effects on poor men and women.

Section 2 of this chapter provides definitions and explains the rationale as well as design aspects of environmental fiscal reforms. Section 3 discusses competitiveness issues and presents options to cushion possible negative effects on industries. Section 4 focuses in on the use of revenues as a particularly important design feature. In section 5, the environmental fiscal reform in Germany is highlighted as a case of green industrial policy success and a practical example of many of the environmental fiscal reform design options discussed. Overall conclusions are drawn in section 6.

2. ENVIRONMENTAL FISCAL REFORMS

2.1. DEFINING ENVIRONMENTAL FISCAL REFORMS

Environmental fiscal reform is a political process aimed at putting a price on environmentally harmful behaviour through the use of fiscal reform tools. These tools include a range of environmental taxes, fees and charges, as well as channelling the revenues toward particular targets. The Organisation for Economic Co-operation and Development (OECD) defines environmentally related taxes as “any compulsory, unrequited payment to general government levied on tax bases deemed to be of particular environmental relevance” (OECD 2006: 26). Environmental fiscal reform also covers the removal of supports or subsidies that are environmentally harmful, such as tax exemptions for kerosene or subsidies for coal.

Within environmental fiscal reform, the narrower concept of an environmental tax reform is, according to the European Environment Agency, a “reform of the national tax system where there is a shift of the burden of taxation from conventional taxes, for example on labour, to environmentally damaging activities, such as resource extraction or pollution. The burden of taxes should fall more on ‘bads’ than ‘goods’ so that appropriate signals are given to consumers and producers” (EEA 2005: 84). Environmental tax reform is a subset of environmental fiscal reform.

2.2. THE RATIONALE BEHIND ENVIRONMENTAL FISCAL REFORM

Before discussing effects and design principles, it is important to understand what environmental fiscal reform instruments are meant to accomplish. They are useful to achieve a range of goals that can be broken down into three broad categories:

1. Benefiting the environment
2. Raising fiscal revenues
3. Increasing fiscal efficiency and competitiveness

BENEFITING THE ENVIRONMENT

The most common rationale for environmental fiscal reform is its positive environmental impact. This environmental benefit is often referred to as the first dividend of environmental fiscal reform (Goulder 1995). Increasing the price of environmentally harmful products or processes by taxing them discourages their use through a market mechanism. This type of government intervention corrects a market failure if the environmental damage of a given action constitutes an externality. Negative externalities arise whenever the actions of one party harm another party and the first party does not bear the full cost of their harmful actions (Gruber 2011). Market actors receive a distorted price signal because the externalized costs are not included in the price paid by the actor. Increasing the price of environmentally harmful products or processes, to the extent of fully internalizing the external costs, incentivises actors to limit their harmful behaviour. The environmental fiscal reform intervention thus gives market actors a correct, or at least a more accurate, price signal—one that better reflects the full and thus true costs of their actions.

Market actors have free choice whether to curb their actions or to pay a price, which is very much in line with the philosophy of a market economy. They can individually adapt their behaviour and will choose or develop the least cost options to avoid environmental damage. Theoretically, this leads to a situation in which a given environmental objective is achieved at minimal cost.

This internalization of external costs is thus a very attractive concept. In practice, estimating the external cost of certain actions can be a complex process–even for something as simple as producing, using and disposing of a plastic bag. Nonetheless, a variety of methods are used to estimate various costs imposed by pollution including costs to health, to productivity, and to the environment. Much progress has been made, allowing us to fairly accurately assess the external costs in many areas, particularly in transport (Freeman 2003; Schwermer 2012a, 2012b; Schwermer et al. 2014; Parry 2014).

RAISING FISCAL REVENUES

Raising revenues for government spending is the second obvious benefit of environmental fiscal reform. Be it through taxes, fees and charges; through the removal of environmentally harmful subsidies; or through auctioning pollution allowances: environmental fiscal reform enables governments to collect funds, thus easing the pressure to collect funds from other areas. The funds can then be spent in various ways–to balance the budget, reduce overall public debts, reduce other taxes, reduce social security contributions or increase spending. The funds can be channelled towards general consumptive or environmental purposes. Spending can also finance research and development for technological innovations or fund infrastructure required for a green transition. Revenues can furthermore be used to compensate vulnerable groups, individuals or companies for increased prices that can result from the implementation of environmental fiscal reform instruments.

Practice has shown that the administrative costs involved in raising environmental taxes are often comparatively low. Environmental taxes, and energy taxation in particular, have the advantage of being relatively easy to administer and therefore may prove particularly attractive in countries where tax collection mechanisms are not yet well developed. The underlying rationale is that energy taxes, such as on petroleum products, can usually be levied from a very limited number of actors–importers, refineries and depots–and are therefore relatively simple to administer and enforce. Even when energy taxes are collected at the points of sale, metering infrastructure is often already in place, such as at petrol pumps or electricity meters (Fay et al. 2015). For example, in Germany the administrative costs of environmental tax reform are estimated at just 0.13 per cent of the revenues raised (OECD 2006).

INCREASING FISCAL EFFICIENCY AND COMPETITIVENESS

Environmental fiscal reform can improve the efficiency of fiscal systems by removing distorting effects. Regular taxes, such as payroll taxes, distort markets in a way that makes certain goods and services artificially unattractive and creates a loss of economic efficiency, in this case for labour. Environmental fiscal reform can ease the pressure on governments to tax labour by providing an alternative source of revenues, thus opening fiscal space to reduce labour costs, to remove labour market distortions and ultimately to increase employment. This is another dividend of environmental fiscal reform (OECD 2000).

When environmentally harmful behaviour becomes more expensive, market actors search for, and tend to find, ways to achieve their goals by changing their production and consumption patterns. If revenues from energy taxes on fossil fuels are used to reduce taxes on labour, labour becomes more attractive relative to production factors that rely on the use of energy. Therefore, energy tends to be substituted by labour. Ideally, people's knowledge and engineering capacities find innovative ways to use energy more efficiently and to substitute fossil energy with renewable energy sources. Several studies find that when structural unemployment[15] exists in an economy, environmental tax reform can boost employment and profits (Bovenberg and Van der Ploeg 1998; Holmlund and Kolm 1997; Schöb and Koskela 1996).

A high tax on the use of fossil fuels and on related emissions makes investments in alternative forms of energy production more attractive, leading to innovation in these fields. According to the Porter Hypothesis, environmental regulation can help businesses to overcome market failures in innovation, thereby allowing them to gain an advantage over their competitors from countries without taxes that incentivise innovations (Porter and Van der Linde 1995; Ambec 2017, this volume). Innovation, in turn, can lead to job creation in new and possibly politically favoured industries. If revenues are recycled to fund environmental innovation, lower tax rates may be needed to achieve environmental goals because switching to alternative technologies becomes cheaper.

2.3. HOW ARE THESE RATIONALES TRANSLATED INTO PRACTICE?

Countries in Europe are at the forefront of designing and applying environmental fiscal reforms, having started in the late 1980s, intensifying their efforts in the 1990s, and further refining these reforms since then. In most cases, energy and carbon dioxide are at the core of environmental taxation, but they are often complemented by taxes on transport, waste and land use (Vivid Economics 2012). Most countries used these revenues to reduce labour costs and increase employment, since unemployment was the major political concern at the time of their introduction. As well, most countries apply a revenue-neutral approach, thus matching the new environmental tax with corresponding reductions in other areas.

In addition to environmental taxation, in 2005 European countries decided to introduce a carbon emissions trading system. In an emissions trading system, governments set an overall limit on emissions and distribute permits or limited authorizations to emit up to the level of the overall limit. The governments may sell the permits; but in many existing schemes they grant permits to regulated polluters according to specific criteria—for example, a baseline derived from each polluter's historical emissions. To demonstrate compliance, polluters must own permits at least equal to the quantity of pollution they emitted during a given time period. Polluters can emit less than allowed by their permits, and sell the excess; or emit more than allowed, and buy permits from other participants. In effect, the buyer pays a charge for polluting and the seller gains a reward for operating with reduced emissions.

In theory, emissions trading and carbon taxes have very similar features; but in practice, carbon and particularly energy taxes are easier and quicker to implement. Most countries already have tax systems in place, while they would have to set up emissions trading schemes from scratch (Pegels 2016). Furthermore, trading schemes often turn out to be ineffective in practice. Since emission permit prices are frequently far too low to influence investment decisions, the major objective of the trading system is not achieved. Without going into detail on the various reasons underlying this observation, one conclusion from the European experience is that energy and carbon taxes should fill in, at least for the interim time until trading systems are delivering as intended. This could be achieved using a carbon floor price that ensures at least a minimum price has to be paid for all emissions.

The Eastern European countries that joined the EU in 2004 have various long-established systems of environmental fees and charges mainly addressing air and water pollution, but including several product taxes. Their approaches provide useful and inspiring examples for less developed countries as they design and implement their sustainable development (Schlegelmilch 1999).

When they joined the EU, many of these Eastern European economies were quite weak and had relatively low administrative capacities; however, they had established comprehensive systems of environmental fees and charges. These fees and charges enabled funding for at least some environmental infrastructure. While far from sufficient, they accomplished more than would have been possible otherwise, since official state budgets provided hardly any funding for environmental purposes. In effect, these fees and charges applied the polluter pays principle and provided incentives to avoid pollution, although the incentives were not strong enough to produce substantial effects (Schlegelmilch 1999). Countries that are currently industrialising can explore the options of following this model or of directly

15 Structural unemployment exists in an economy in which wages are slow to adjust and labour is relatively immobile between sectors. Changes in demand and in production technology can create structural imbalances in the labour market so that at a given wage, the supply of labour is higher than demand.

leapfrogging to the approach of comprehensive environmental fiscal reforms.

Experience from developing country peers also can provide valuable guidance. A useful comparative study of several African and Indian Ocean island states, for example, provides detailed insights into how developing countries can transition from fossil fuels to renewable energies, including through the application of environmental fiscal reform elements (Cottrell et al. 2015). The lessons learned from these island states provide constructive insights. In many of these countries, energy taxation is the most important element they use. Several countries direct these revenues to promotion of energy savings, efficiency and renewables. These countries face significant challenges, including rising sea levels and storms worsened by climate change, while depending on fossil fuel imports. Moving to energy independence through renewable sources and greater efficiencies is a very attractive goal.

3. MANAGING EFFECTS ON COMPETITIVENESS

From an environmental perspective, full internalization of environmental costs would be the priority aim of reforms. In practice, however, competitiveness and social consequences need careful consideration, and both aspects are important factors in the design of an effective environmental fiscal reform, particularly in the revenue-raising component of environmental taxes. Ideally, environmental fiscal reforms can have neutral or even positive effects on competitiveness at firm, sectoral and national levels; and, in practice, many have been shown to produce positive outcomes (Pegels 2016). However, negative effects on individual industries are possible. In the following subsections, the potential for positive versus negative effects on competitiveness are discussed first. Then, various options are presented that show the potential to reap positive and manage negative effects, particularly through the combination of tax exemptions with negotiated performance agreements, carbon border adjustments, and international coordination on environmental pricing. The subsequent section 4 discusses how effective design of revenue recycling components can help environmental fiscal reforms avoid negative social consequences.

3.1. POSITIVE OR NEGATIVE EFFECTS?

When considering how to prevent possible negative effects on competitiveness, it is important to recall the rationale for environmental fiscal reform: the implementation of the polluter pays principle and the internalization of external environmental damage costs. “By seeking to protect the environment, environmentally related taxation is by definition intended to distort production decisions and have a disproportionate impact on polluters” (OECD 2010: 144). Thus, the very objective of environmental fiscal and, more narrowly, tax reform is to create a competitive disadvantage for those companies that pollute or are less energy-efficient, while also providing incentives to reduce pollution by the most efficient means at their disposal. At the same time, the taxes create a competitive advantage for firms with environmentally sound products and processes. As instruments of green industrial policy, environmental taxes can have positive effects on competitiveness–as demonstrated by numerous examples:

- Environmental taxes can spur innovation when price changes trigger improvements in products and production processes (Görlach et al. 2005).
- Environmental taxes can spur economic growth as demonstrated for six EU countries in a targeted research project report. All six countries achieved an increase in GDP of up to 0.5 per cent compared to a baseline without the environmental tax reform measures, while CO_2 emissions decreased. The report states, “As a general rule, the effects of the [environmental tax reform] will be positive on economic activity, depending on how the revenues from the environmental taxes are recycled. However, it is likely that there will be transition costs, so the gains may not be immediate” (COMETR 2007: 41–42).
- Companies may benefit from reducing costs by increased efficiency, but also from growing markets for the environmentally sound products they are either selling, applying, or both. This has been shown for several companies in Germany (Knigge and Görlach 2005).

These benefits demonstrate the potential positive effects for the industry. These examples of energy tax outcomes show that competitiveness concerns usually relate only to a few energy-intensive sectors and are frequently exaggerated, for several reasons (Green Fiscal Commission 2010):

- Fluctuations in energy prices on global markets tend to be far more significant than the effect of a tax on energy.
- Not all energy-intensive goods are highly traded internationally; in these cases, increased costs can be passed on to the consumer.
- An increase in energy prices will incentivise both energy efficiency measures and innovation, which may result in stable or even falling energy costs for firms over time.
- Revenues can be used to counter negative effects and to support investment in reduced energy use or installation of appropriate technologies.

Fears about energy price increases expressed by companies can prompt governments to over-compensate industry. During discussions with industry regarding the impact of such measures, the regulator has less information than business—an information asymmetry that puts business at an advantage in negotiations. In some cases, the cheapest possible energy price is not a top priority for business (Box 7.1).

Box 7.1: Factors influencing foreign direct investment in Vietnam

A 2015 review of investor sentiment in Vietnam revealed that increased energy prices do not exert a significant influence on the investment decisions of those looking to make foreign direct investments. Instead they are concerned by a lack of skilled human resources and an unreliable electricity supply.

In general, private investment is affected far more by regulatory conditions and the political situation in the country in question. In Vietnam, six basic problems act as a major barrier to investment, according to representatives of government interviewed in the Vietnam Economic Times:

- No transparency
- No consistency
- No synchronization
- No stability
- No possibility, an issue which is presumably related to a lack of policy reform in the country
- No predictability.

Neither environmental taxation nor energy prices were mentioned.

Source: Garg et al. (2015); Cottrell et al. (2016).

Although the OECD conducted several studies to detect the risk of industry relocation as a result of environmental taxation, there is no substantial evidence that it occurs (Arlinghaus 2015). Hence, at least in the OECD context, the supposed trade-off between achieving environmental objectives and maintaining competitiveness of energy-intensive industries does not seem to exist.

When governments decide to apply protective measures, such as reduced tax rates or even full exemptions, they may combine them with negotiated performance agreements, such as the introduction of an energy management system, and limit their duration. Yet, it is important to take into account that all those exemptions also have negative effects on competitiveness. This could be discouraging for the existing energy-efficient, resource-light industries already contributing to the economic transformation that green industrial policy pursues; while it also removes incentives for other industries to become more efficient. In the UK, for example, exemptions for industry have resulted in energy-intensive sectors missing the low-hanging fruits of energy efficiency investments (Cottrell et al. 2017).

3.2. REDUCED TAX RATES

Reduced tax rates are the most widely applied protective measure for industries and thus are a major element of many environmental fiscal reforms. Almost all countries provide reduced tax rates for industries, while other consumers have to pay the full rates. Sometimes tax rates are reduced for all industries, sometimes only for those that are energy-intensive and face international competition. When used, tax reductions and refunds must avoid overcompensation (Box 7.2).

Box 7.2: Germany's tax exemptions for industry: Leaving efficiency potentials untapped

In Germany, energy-intensive companies in the manufacturing sector receive a refund of 90 per cent of their energy and electricity taxes, even though the Federal Environment Agency has estimated that this subsidy almost completely neutralizes the environmental tax. These exemptions were due to be phased out in 2012, but were extended to 2020. Energy management systems have been made compulsory, as have annual energy savings of 1.3 per cent from 2012 to 2015 and 1.35 per cent for 2016. Annual energy savings between 1991 and 2009 have been well above the planned rates of 1.3 per cent and 1.35 per cent. Thus, these rules and associated subsidies are not compelling anything. Instead large potentials for efficiency and pollution reduction remain untapped in Germany's energy-intensive industries.

Sources: Andersen and Ekins (2009); Roland Berger (2011); BMWi (2013); UBA (2016).

The United Kingdom has a different problem. The major concern regarding energy and carbon taxation in the UK is not industry, but the affordability of heating for private households. Badly insulated houses and a relatively cool climate result in fuel poverty. Policymakers thus shy away from taxing heating fuels. Hence, the UK applied a climate change levy, which was imposed on industry only, not on private households. However, energy-intensive industries also managed to receive substantial reductions to protect their competitiveness. Consumption-dependent thresholds for the reductions led to an unequal distribution of the burden of the levy, favouring energy-intensive and mostly large businesses over small and medium-sized enterprises.

These examples illustrate how tax reductions produce negative effects. First of all, when the environmental damage caused by an actor, such as energy consumption, is the basis for granting tax reductions, those who damage most receive the highest benefits. They will then be the last to adapt their behaviour towards protecting the environment. Only proper pricing will ensure and promote an efficient allocation of resources across sectors over the longer term. The argument of carbon leakage—industries relocating to low-tax countries—applies only to a small group of industries that have both high energy costs and strong international competition. Among those sectors could be lime, cement, iron, steel, aluminium, refined petroleum, fertilisers and nitrogen, starches, pulp and paper and basic chemicals (Dröge et al. 2009). However, as mentioned above, the OECD could not find substantial evidence of this behaviour (Arlinghaus 2015).

Exemptions and reductions are also unattractive for administrative and political reasons. Each exemption and special treatment of a tax increases its complexity, and therefore its administrative costs, and opens the door to rent-seeking behaviour. Accurately discriminating between those who should be eligible for a tax exemption and those who are not, based on defined criteria, is complicated. Offering a lower tax rate to industries that qualify, according to specific indicators of how their international competitiveness is threatened, often compels firms to shift their behaviour to fulfil these criteria, rather than to increase efficiencies or reduce pollution. This distorts markets in unpredictable ways.

If reductions are provided nonetheless, they should at least be combined with compensatory measures, such as negotiated agreements, concrete investment commitments or, preferably, mandatory energy management and auditing requirements.

3.3. LINKING REDUCED TAX RATES TO NEGOTIATED AGREEMENTS

Negotiated agreements with industry might also be a way to safeguard environmental action when industries are exempt from environmental taxes for competitiveness reasons. For example, industries and their associations can commit to target-oriented action, forestalling regulatory legislation and other instruments such as environmental taxation. Sometimes referred to as voluntary agreements, that term does not capture the true nature of most negotiated agreements since they usually result from the threat of binding requirements (Héritier and Lehmkuhl 2008).

Reliable evaluations of negotiated agreements are still scarce, in contrast to other instruments, such as taxes. This may be due to their relative novelty in the policy arena. Complicating the analysis further, often targets are not quantified or, if they are, important parameters such as the baseline are unclear.

Very few negotiated approaches have been tried in combination with environmental taxation. Hence, there are not many conclusions to be drawn. Switzerland had negotiated an environmental agreement regarding heating emissions combined with the taxation of heating fuels. It was agreed and noted in the CO_2 law that if emissions do not decrease according to fixed interim targets, the tax rate would be increased. After the emissions had not decreased sufficiently in 2014, the government increased the CO_2 levy by almost 25 per cent in 2016 (BAFU 2016). Hence, in the end, this agreement has only postponed implementation of effective instruments and delayed effective emission reductions and green investments.

Another example occurred in Germany, where a negotiated environmental agreement was connected to tax reductions for the manufacturing industry. When the tax reductions were granted, there was no initial specification of substantial and concrete compensatory measures that industry should take–only a rather vague mention of general industry contributions to achieving emission reductions. Even this vague formulation was not voluntary, but resulted from the threat of otherwise stricter energy taxation. After the introduction of the tax reductions, the German government faced pertinent questions from the European Commission about how to ensure industry's contribution to climate targets despite reduced incentives. This led to the specification of the non-binding target in the negotiated agreement to reduce emissions by 20 per cent. The agreed baseline of 1987, which was later changed to 1990, allowed industry to benefit from the emission reductions resulting from the German reunification and, more specifically, the modernisation of Eastern German industry. Due to these influences, emissions decreased by about 15 per cent between 1987 and 1993, thus significantly reducing the level of ambition of industry's commitment to decrease emissions in any substantive sense (Böcher 1996: 193).

Different industrial sectors of Germany's economy are still benefiting from the energy and electricity tax reductions in the order of EUR 7.6 billion per year, according to the subsidy report of the Government (BMF 2015: 17). As well, industry benefits from reduced social security contributions. The European emissions trading scheme further supports avoiding cuts while complying with its environmental agreement by providing the option of buying permits instead of pursuing actual emission reductions by each firm. Hence, industry is supported substantially by the combined policy package.

3.4. LINKING REDUCED TAX RATES TO ENERGY MANAGEMENT REQUIREMENTS

When negotiated agreements are not considered binding enough, environmental tax reductions can also be linked to mandatory requirements, such as installing energy management systems. They contribute to overcoming the potential dilemma between providing direction and the competitiveness of industries. Though tax rates and incentives are reduced, industry takes concrete action to reduce emissions.

The aim of energy management requirements is to support the identification and implementation of profitable energy saving potentials. They typically comprise two major elements:

- The introduction of a comprehensive data monitoring system to establish how much and what kind of energy is used when and where
- The realisation of concrete energy-saving potential and thus possible measures, as changes of behaviours and processes or of investments.

Such a requirement can be considered a no-regret option, because it does not put a real burden on the companies, apart from some administrative costs. It supports companies in establishing a data information system on energy flows and greenhouse gas emissions, increasing transparency. On this basis it is much easier to identify concrete investment options for improving energy efficiency and the use of renewable energies. This combination of instruments, carbon/energy taxation and energy management systems, has been applied in the United Kingdom, for example, where positive experiences were noted (Government Digital Service n.d.).

Often this instrument combination can be differentiated into two further options:

- Establishing just the data information flow, while still identifying options for investments and changes of behaviour in case future steps are anticipated as possible
- Exploiting these potential options by implementing measures in a certain time frame.

The former option basically comes without added costs, apart from the administrative efforts, but it brings about benefits in the form of more transparency on energy and of cost-saving potentials. Its application can therefore be generally recommended. Several countries implemented this option, among them Germany and Denmark (UNIDO 2015). The latter option may involve substantial costs for the companies. Hence, the potential design element of requiring the implementation of these identified investment options should be applied with more care. Here, the investment cycle is likely the most important criterion to be taken into account: when replacement investments are due anyways, a switch to more efficient machinery results in lower marginal costs. Assuming that the energy management requirements take the investment cycle into account and include minimum requirements for profitability, the second option can be recommended.

3.5. BORDER CARBON ADJUSTMENTS

Border carbon adjustments offer a trade mechanism to counterbalance potentially higher costs due to domestic environmental taxation, thus levelling the playing field between countries with higher environmental taxation and those with lower or none. The aim is to allow countries to be frontrunners and not to punish them by endangering their industries. In practice, this would mean that products from countries with a lower level of environmental taxation would be charged at the border by an environmental tax of a level similar to the domestic one.

A border carbon adjustment could also include relieving exported products from the part of the energy taxation that exceeds the level encountered abroad. Hence, border carbon adjustments offer an effective means of ensuring the competitiveness of energy-intensive industries while still incentivizing industry to take ambitious actions towards climate change mitigation.

Practical examples include the tax on ozone-depleting chemicals in the US and on primary construction materials in Denmark, called the gravel tax (Internal Revenue Service 2007; Christensen 2011; Wageningen University & Research 2016). However, border carbon adjustments have not been applied more broadly, since most countries shy away from the risk of triggering trade wars. The targeted country or its industries might consider a border carbon adjustment an unfair measure, since it could be considered disguised protectionism if not adequately designed, introduced, communicated and implemented.

3.6. INTERNATIONAL COOPERATION AND COORDINATION OF CARBON PRICING

International cooperation and coordination is likely to be an effective way of avoiding competitive disadvantages. However, there are only a few practical cases where a minimum of cooperation could be achieved.

One example is the agreement of September 2016 between the Canadian provinces Ontario and Quebec and extending their cooperation on climate change with Mexico. They all agreed to work more closely on carbon tax policy (Cleantech Canada 2016). Another example is the European Union: Since 2004, there has been a common framework for energy and carbon taxation in the EU that requires at least minimum energy tax rates on all energy products in all EU Member States, while any country is free to exceed these rates (EU 2004).

4. RECYCLING OF REVENUES

As stated earlier, environmental fiscal reforms do not only set incentives for structural change by shifting the competitive positions of industries, but they have the additional benefit of raising government revenues. There is a longstanding and ongoing debate about the best way to allocate these revenues (OECD 2005; World Bank 2005). However, since revenue raised through environmental fiscal reform is equivalent to all other revenues, the actual issue is how government revenues in general should be spent. It should be clear that there is no straightforward answer. However, there are some common spending options.

Probably the most sensible way to recycle environmental revenues is to evaluate them from a political and strategic perspective. One strategy worth considering is to identify the highest national political priority, which may not be related explicitly to the environment, and use the environmental revenues toward this aim. A second approach is to identify winners and losers from the environmental fiscal reform and use the revenues to mobilize powerful stakeholders and seize opportunities to build coalitions. Political and economic leaders who have the perseverance to lead the process through the inevitable challenges are key to the success of environmental fiscal reform. Approaching spending choices from this very practical point of view can be reasonable, given that spending decisions are fundamentally political in character. Thus, assigning environmental revenues to policy priorities and strategic uses can be key factors for building reform coalitions successfully.

4.1. EARMARKING—PROS AND CONS

Earmarking the revenues for particular purposes can be an option to demonstrate transparently how the revenues are used, which facilitates communication. The advantages and disadvantages of four particular earmarking options invite analysis: green investments, tax shifting, offsetting potentially negative effects on competitiveness and managing effects on poor people and particularly vulnerable groups in society such as women and youth.

The concept of earmarking requires some context. First, the constitutions of many countries do not allow earmarking (Box 7.3). Also, the practice can complicate budget processes because it invites interest groups to lobby for certain revenue streams to fund their interests. Finally, it may prove problematic when earmarked revenues do not match the need of a particular spending project. This was the case for the UK Climate Change Levy revenues that were earmarked to fund reduced national insurance contributions, but did not raise sufficient revenues to match the reductions (Cottrell et al. 2013). Although attractive from a communication point of view, earmarking revenues can be unattractive from a fiscal point of view. Both politicians and finance ministries generally demand the freedom to allocate revenues according to current requirements (World Bank 2005).

Box 7.3: Earmarking in Chile

Chile's Centro de Investigation y Planification del Medio Ambiente explored options to develop a sustainability fund for the mining sector. The proposed fund would support sustainability issues, serve to diversify production, integrate mining companies into the community and help to conserve water and biodiversity. The public sector and mining companies would finance it voluntarily. However, it would be difficult to base the fund on taxes: Any change in the tax system that allocates revenues to a specific purpose requires a presidential decree or a change in the constitution because Chile's constitution prohibits it.

Source: Schlegelmilch and Joas (2015: 55f.).

4.2. EARMARKING REVENUES FOR GREEN INVESTMENTS

One way to spend environmental revenues is to earmark them for environmental spending. This may be intuitive, as taxpayers understand that price increases resulting from environmentally harmful behaviour are financing investments in environmentally-related public goods. If the goal of an environmental fiscal reform is to reach certain environmental targets, green spending can help to accelerate the process. If funds are used in this way, tax rates to achieve a defined environmental target can be lower. The targeted

EU research study produced a model demonstrating that emission reductions could be achieved, along with substantially lower tax rates, if 10 per cent of revenues were invested in energy efficiency measures alone (COMETR 2007).

Spending options can, for example, include subsidies for research and development on clean technological solutions. They can also include directing funds into green infrastructure like public transport, smart grids, buildings or renewable energy systems. This way of pricing positive externalities is much in line with the spirit of industrial policies and is often much appreciated by industry since it is an incentive rather than a punishment. Nonetheless, it must be noted that connecting environmental revenues to outright subsidies for certain groups may encourage rent-seeking behaviour among the recipients (UNEP 2010). While strategic use of revenues can increase the likelihood of the fiscal reform's continuation, without good management, recipients might grow dependent on payments.

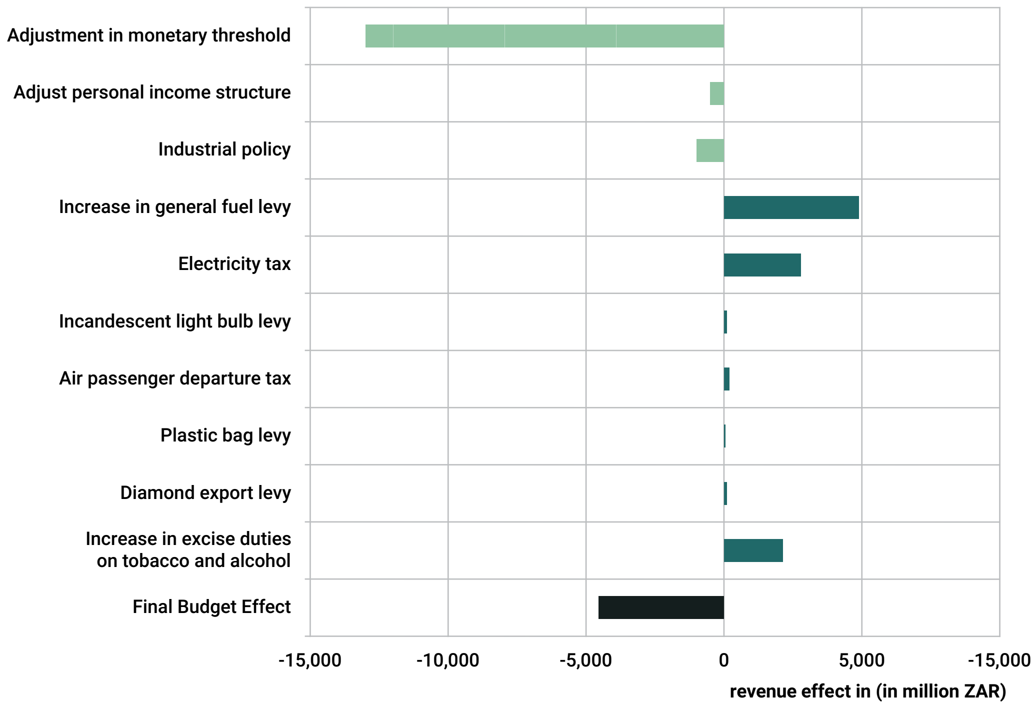
4.3. ENVIRONMENTAL TAX SHIFT

Recycling revenues to lower other distorting taxes in the economy is a common use of environmental revenues. The revenues from Germany's environmental tax reform were used mostly to lower pension payments that were increasing labour costs and thus contributing to unemployment. Recycling revenues to lower distorting taxes is often described as leading to one of the dividends of environmental fiscal reform, since this step creates wealth by removing existing distortions, such as tax-induced unemployment (Jaeger 2012). Using environmental revenues to lower distortive taxes such as taxes on labour is an attractive option to maximise economic welfare, but requires the identification of the most distortive taxes. This is likely to vary according to country conditions.

One aspect to keep in mind, however, is the need to balance market efficiency with social desirability. For example, Takeda (2007) finds that strong double dividend effects arise when revenues are recycled by lowering taxes on capital but not on labour or consumption. While this may be economically correct, it could result in socially undesirable outcomes, such as more inequity and injustice within the tax system, as well as in political risks and destabilization. This might result, for instance, in a case where an environmental tax was raised from a large group of actors and the revenue used to lower taxes on capital, which would benefit only a small group that is likely well off already .

An example for tax shifting is the South African 2009 budget in which the South African Revenue Service proposed a tax reduction worth ZAR (South African Rand) 13,500 million to personal income taxes and another ZAR 1,000 million to business taxes (Speck 2010). Had the proposal been implemented, most of the tax cuts would have been compensated by increasing indirect taxes, mainly fuel and electricity taxes. These measures would have contributed to the progressiveness of the tax system, thereby reducing inequity. The overall effect would have been a loss of revenues worth ZAR 4,575 million (Figure 7.1). Environmental fiscal reforms are not necessarily revenue neutral–they can also lead to a net increase or decrease of revenues.

Figure 7.1: Financing income tax cuts through environmental fiscal reform in South Africa: The revenue effects of various reform elements



Source: Adapted from Speck (2010).

4.4. OFFSETTING NEGATIVE IMPACTS ON COMPETITIVENESS

Some revenues could be earmarked for mitigating or reducing potentially negative effects of environmental taxes on the competitiveness of some industries, by reducing other taxes such as corporate or labour taxation or by providing targeted grants to co-finance investments in energy efficiency. This can be a way to address competitiveness concerns regarding firms in other countries that do not face similar taxes. Firms that have already taken steps to reduce pollution should be preferred, rather than simply returning taxes paid to polluter and pollution reducer alike (OECD 2005). Furthermore, it is also important that compensations are designed in a way that does not encourage firms to produce more emissions (World Bank 2005). Revenue recycling might be an effective way to encourage industry acceptance of reforms. In China, for example, a combination of pollution taxes and support for pollution abatement expenditures has proven to be effective (Barde et al. 2009). Sweden applied a charge on nitrogen oxide emissions, but it recycled revenues back to the same sector, utilities, on the basis of each company's electricity generation (OECD 2013). This way, it favoured clean and efficient companies while protecting competitiveness.

4.5. OFFSETTING NEGATIVE IMPACTS ON THE POOR

Protecting the poor is a prerequisite for any environmental fiscal reform, particularly in developing countries. At the same time, it is important not to undermine incentives to reduce energy and water consumption (OECD 2005). Differentiated pricing for different types of users can be an effective option, as targeted cash transfers can be. Since this chapter focuses on environmental fiscal reform as a green industrial policy, inclusiveness is not discussed in much detail. Nonetheless, a practical example of Indonesia's Bantuan Langsung Tunai is useful to demonstrate the potential for cash transfer programmes in raising a population's acceptance level for environmental fiscal reform (Box 7.4).

Box 7.4: Raising acceptance for environmental fiscal reform through cash transfer programmes: The Indonesian *Bantuan Langsung Tunai*

In the aftermath of the Asian financial crisis in the late 1990s and early 2000s, Indonesia initiated attempts to reduce fossil fuel subsidies, which had neared 20 per cent of total domestic revenues. The savings were initially recycled through general spending, specifically health-care and education. Since the economic crisis and a regime of corruption, collusion and nepotism had already built social discontent, the subsidy reform steps triggered violent demonstrations. A hike in global oil prices challenged reform implementation even further. In 2005, the Indonesian government nonetheless removed subsidies for industrial users and raised gasoline and kerosene prices by more than 150 per cent within one year. Despite the immense increase of fuel prices, opposition against the reform was relatively moderate. This can be explained by the simultaneous introduction of the compensation programme Bantuan Langsun Tunai. The programme was a targeted and well-communicated, unconditional cash transfer to compensate poor households. All households with monthly fuel expenditures below the threshold of IDR (Indonesian Rupiah) 175,000 received monthly payments of IDR 100,000 over six months. Twenty-eight per cent of all Indonesian households received those payments. Between 2005 and 2006, compensatory spending for the programme amounted to EUR 1.93 billion and made up more than 50 per cent of the saved spending from subsidy cuts in 2005. Nonetheless, the subsidy reform contributed substantively to reducing the state budget deficit.

Sources: Beaton and Lontoh (2010), Widjaja (2008), World Bank (2012).

The Indonesian case illustrates that while environmental fiscal reforms maintain their economic and environmental appeal, policymakers need to be prepared to recycle large parts of revenues to those who cannot easily carry the burden of higher prices. In another study, Schlegelmilch (2011) analyzed conditions and suggested concrete steps for Indonesia to continue environmental fiscal reforms. The suggestions build mainly on the good tax bases at Indonesian local levels, which are often based on natural resource use and other environmentally relevant activities. Hence, there is hardly any need to introduce new taxes, since many of the existing taxes could simply be increased. These increases would alleviate the necessity for payments from the federal to the local level. This, in turn, would free funds on the federal level, which could be used to lower federal taxes, for example on income, or invest in targeted programmes to reduce poverty.

5. GERMANY’S ENVIRONMENTAL FISCAL REFORM: A GREEN INDUSTRIAL POLICY SUCCESS STORY

The implementation of environmental fiscal reform in Germany can be considered a green industrial policy success story. The effort was undertaken against the background of high unemployment, the top national priority at the time of implementation, and the need to reduce greenhouse gas emissions.

The reform was implemented between 1999 and 2003 and consisted of the following main elements:

- Transport and heating fuel taxes were increased.
- An electricity tax was introduced in 1999 and increased between 1999 and 2003.
- Social security contributions were reduced.
- Reduced tax rates were granted for energy-intensive companies and the manufacturing industry.
- Reduced tax rates were granted for several environmentally-sound activities.
- Minor parts of the revenues were used for promoting renewable energies and energy efficiency in the buildings sector.
- Overall, the environmental fiscal reform was almost revenue neutral.

As settled in the coalition agreement of 2002, the environmental fiscal reform was evaluated in 2004 in a series of studies to assess if and how it should be continued. Model-based estimates of its outcomes came to the conclusion that positive effects could be expected and a double dividend was likely to be achieved in comparison to a reference scenario without the environmental fiscal reform (Kohlhaas 2005; Bach et al. 2001). These positive effects include:

- Reduction of CO_2 emissions by about 2–3 per cent and a lasting reduction of fuel sales
- Creation of up to 250,000 additional jobs, assuming that the employment gains would not be accompanied by higher wages
- A slightly positive effect on GDP.

While causation can be difficult to prove, other studies found interesting correlations (BMF 2004: 35–43; BMU 2004: 16–18; Schlegelmilch 2005: 10–12; Bundesverband CarSharing 2016):

- After decades of decrease, the number of passengers using public transport started increasing from 1999 and was about 7–8 per cent higher in 2006.
- The number of members of car sharing organizations has been steadily growing since 1999, sometimes with two-digit percentage numbers, and has reached more than 1.2 million drivers in 2016.
- The manufacturers of solar water heaters similarly experienced strong growth—originating not only in the higher heating taxes, but also in a funding programme providing grants financed by the environmental tax revenue.

The sharply increasing crude oil world price at the period of analysis–from about US$ 18.00 per barrel in 1998 to about US$ 39.00 in 2000–certainly played a role in causing some of these effects, and the individual influences can be challenging to isolate. But undoubtedly, the various efficiency gains, cost-savings, tax reductions, market expansions, and innovations stimulated by environmental fiscal reforms improved the competitive position of many German companies (Knigge and Görlach 2005). However, industry associations mainly stressed negative effects. Meyer et al. (2001) provide an enlightening analysis of the discourse in the wake of the tax reform implementation, when industry associations and well-organized energy-intensive enterprises acted as strong and vocal vetoes.

Another reason for opposition may be the emphasis of early discussions and the first draft of the reform law on potential negative effects for broader parts of industries. Due to these discussions the draft was adapted to its current form. The major barrier, perceived negative effects on some industries, was overcome by reducing more distorting labour taxation such as social security contributions to the pensions fund, but also by providing reduced rates for major industries. While opposition may have persisted in some parts of industry for strategic reasons, that is, to safeguard eligibility for exemptions, the prospect of a double dividend ensured a broad alliance in society including unions and parts of industry. Even when world oil price surged and led to protests, the German government stood firm since reducing unemployment was its top priority at the time, and a major means was the reduction of labour costs. Hence, linking revenue use to the national top priority turned out to be very effective in overcoming barriers and maintaining the environmental fiscal reform.

From a political point of view, it was also very important to rally the winners of the reform: Often enterprises did not know they were benefiting, but perceived themselves as losers before calculating their profits and finding out about the actual results. Some companies did not dare speak out in public in favour of the environmental fiscal reform to avoid positioning themselves against the industry mainstream, which was communicated by the large industry associations. The risk of opposing the mainstream was often perceived higher than the potential benefits of further steps of an environmental fiscal reform.[16]

Several years after the start of the reform, the European Commission increased pressure on the German government to require a solid return in exchange for the state aid to energy-intensive industries in the form of the reduced tax rates. Therefore, the government made the tax reductions subject to the introduction of an energy management system. In 2011, a new government formed by conservatives and liberals implemented further important, though smaller, environmental fiscal reform elements. A study by the Heinrich-Böll-Foundation analysed and recommended several elements, of which the following were implemented (Ludewig et al. 2010):

- Ticket fees on air transport were introduced, differentiated according to the length of flights.
- A tax on nuclear fuel was introduced to increase utilities' share in total costs of nuclear power.
- The heavy goods vehicle toll, introduced in 2005, was extended to cover roads other than motorways.

16 Schlegelmilch (2005), personal communication.

- The industrial exemptions from the energy tax were reduced.
- A financial transaction tax was adopted.

These amendments show that, as sensitive as individual reform elements may be, the environmental fiscal reform as such has reached a cross-party consensus since its introduction. This is a major political success, not least since it ensures investment certainty.

6. CONCLUSIONS

Environmental fiscal reforms are a core element of green industrial policy. They contribute to the relative profitability of green investments and they are easy to administer while having substantive revenue potential, particularly in the form of energy taxes.

Revenues can then be used for such national priorities as poverty reduction, investments in health, green infrastructure and others. Another option is to promote green industries by using revenues to foster research, development, and deployment of clean technologies—an example of supporting positive effects instead of penalizing negative effects. From a political economy point of view, revenue recycling can help to build broad alliances and overcome political resistance.

Competitiveness aspects can be managed by designing tax schemes accordingly. When environmental taxes are applied, enterprises exposed to international competition are eligible for reduced tax rates in most countries. However, if potentials for energy saving and renewable energy are high and efficiencies are low, it may be reasonable to apply taxes without reduced rates. Industry will then be compelled to tap the efficiency potentials, thus reducing costs and increasing competitiveness. Increased efficiency can, on the national level, contribute to an improved trade balance and less dependence on fossil or other polluting energy imports.

An ideal option to protect domestic industries would be to enhance international cooperation and coordination on the introduction of carbon and energy pricing. However, international coordination on this issue is not very developed yet. Many countries have introduced or are considering some form of carbon pricing and recent years have seen the emergence of a number of coordinating initiatives such as the Carbon Pricing Leadership Coalition (World Bank et al. 2016). Nonetheless, there is still large variation in the global prevalence and levels of carbon prices. Until global coordination is more developed, border carbon adjustments could be an option to protect domestic industries by levelling their competitiveness at the border. However, practical application is scarce. The few experiences gained from the case of the Danish primary construction materials/gravel tax and the US ozone-depleting chemicals tax should be further evaluated and fed into an attempt by the European Commission to establish a similar system (Internal Revenue Service 2007, Christensen 2011, Wageningen University & Research 2016). In fact, the European Union would be particularly suited to implement border carbon adjustments, since it is one of the largest global markets, has excellent implementation capacities, and relatively strong political will to establish environmental protection measures. Carbon border adjustments would help to overcome most concerns regarding weakened competitiveness of energy-intensive industries that may currently exist due to the relatively high level of energy prices in the EU.

Linking reduced tax rates to requirements for energy management is also hardly used, although it could be applied at short notice and eventually benefit industry. It is in most cases a no-regret option, because it does not put real burden on industry, apart from adoption costs, but can mobilize substantial savings.

In overall conclusion, environmental fiscal reform can affect the competitiveness of industry both positively or negatively. But even when effects are negative, they tend to be small, and various design options exist to further minimise these effects or compensate the affected industries. Many design options have not yet been exploited, or even explored, to their full potential. From a political point of view, rallying the beneficiaries of reforms is just as important as negotiating with the losers. Often there is a lack of awareness of the benefits they are reaping and, even when aware, stakeholders may not be encouraged to become more outspoken about the positive effects they experience. Understanding the nature of the benefits and communicating the findings will help to build coalitions for change, as will linking the reform revenues to national priority aims, such as employment or poverty reduction.

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CHAPTER 8

PROMOTING CIRCULAR ECONOMIES

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1. INTRODUCTION

In 2017, the Earth Overshoot Day fell on August 2. It marks the date when human demand for environmental resources and services exceeds what nature can regenerate within that calendar year. August 2 is the earliest date since calculations started in 1970 and means that the productivity of not one, but 1.7 Earths would be needed to meet humanity's global demand sustainably (Earth Overshoot Day 2017).

In 2010, global material use amounted to 79.4 billion tons (Schandl et al. 2016). Under a business-as-usual scenario, estimates suggest this annual consumption will rise to 180 billion tons by 2050 (Dittrich et al. 2012). This increase results from the predominance of a linear model of resource consumption in which ever new resources are extracted, used as inputs for production processes and then discarded (Ellen MacArthur Foundation 2013). With this economic model and its inbuilt accelerations, humanity is overstepping Earth's bio-capacity boundary.

To stay within planetary boundaries, economic growth has to be decoupled from resource use and environmental degradation (Rockström et al. 2009). This can be achieved by a transition from the linear model of economic consumption and production to circular economies in which resources are efficiently used and materials can be reused or recycled at their highest possible value, reducing waste–and keeping the extraction of new resources–to a minimum. For this to happen, a product has to be managed differently, throughout its whole life cycle, starting from the way it is designed and how its raw materials are extracted and covering manufacture, transportation and consumption, as well as how thoroughly it is recycled at the end (Wilts 2016). A circular economy can reduce unsustainable exploitation of natural resources while increasing human well-being and economic wealth.

The structure of this chapter is as follows: The second section explains the concept of a circular economy in more detail. The third section provides some practical examples where the principle of closed cycles has been applied at various scales. Section 4 introduces a variety of benefits that come with the implementation of a circular economy. Section 5 explains measures to overcome barriers and encourage the transition towards a circular economy. Section 6 concludes. Throughout this chapter, examples from companies and from countries at various levels of income and human development are used to illustrate how theory translates into reality.

2. WHAT IS A CIRCULAR ECONOMY?

In a circular economy, production and consumption systems are designed in a way that products and waste materials are reused and recycled within the production and consumption system (International Resource Panel n.d.). It builds on reduce, reuse, recycle (3Rs) and explores opportunities to promote closed material loops and high levels of resource efficiency in a system-wide approach. The 3Rs serve as a framework for resource efficiency: Manufactured products need to be designed for long-term use and for reuse, which will encourage repair, refurbishment, and remanufacturing. Lastly, at the end of a product's lifetime, the input material has to be recycled and returned to the industrial process (Jørgensen 2015). With this approach, waste in production, supply, use and disposal is minimised, and a maximum proportion of the original resource is recovered.

The circular economy is commonly described as a restorative and regenerative model that seeks to keep products, materials and resources at their highest value and utility at all times so they can be retained in a closed loop for as long as possible, thereby creating new value (Ellen MacArthur Foundation 2016a). The energy powering this system should come from renewable sources, not from fossil fuels (Ellen MacArthur Foundation 2016b). Non-toxic natural material that cannot be reused eventually returns to nature by being composted. Processed, non-toxic materials, such as glass, steel and plastics, are retained in the system and generate further value beyond the time when they would have been discarded or scrapped in the linear model (Evans et al. 2014). To be able to reuse most of the processed material, products are designed in ways that their input materials can be recovered at high quality levels using minimal energy (Ellen MacArthur Foundation 2016b).

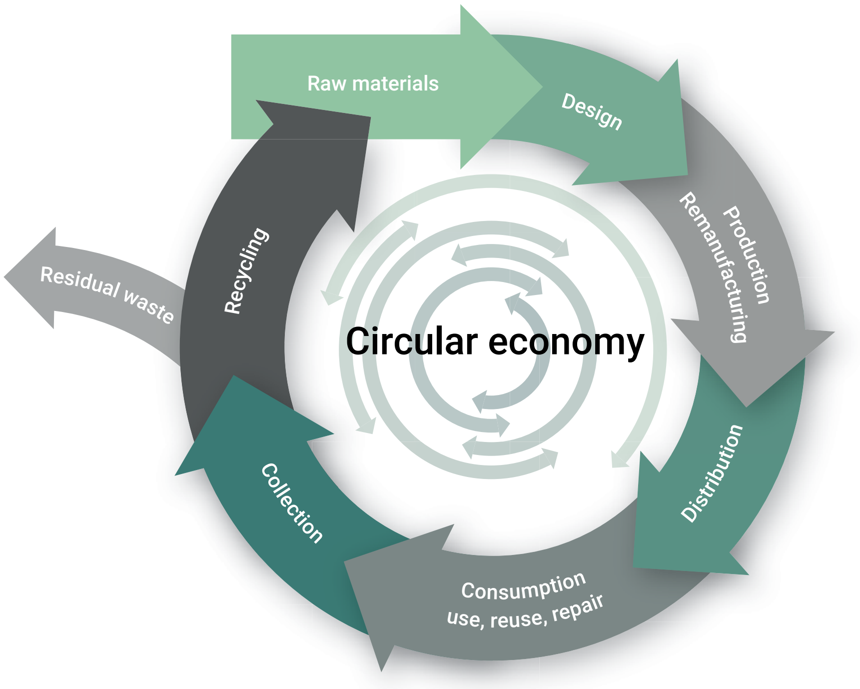

Figure 8.1: Conceptual diagram of a circular economy[17] (Adapted from European Commission 2014)

The circular economy model takes the full life cycle of a product into account (Figure 8.1). Since some small amount of residual waste cannot be avoided, new resources always need to be added to the production process to some extent. However, the aim of the circular economy is to keep this residual waste as small as possible and to rely on recycled resources for the major share of economic processes (European Commission 2014). Therefore, it supports the objective of decoupling the economy from the use of non-renewable energy and of pristine resources. Decoupling refers to removing the links leading from economic growth to resource use and to negative environmental effects (International Resource Panel n.d.). In fact, most economies are now using fewer resources to produce one unit of GDP (UNEP 2016). This is a partial success because it extends the timeframe until economies reach, or further overstep, their environmental boundaries. Yet such relative decoupling can be negated by economic growth and increasing consumption (Wijkman and Skånberg 2015). This case, where resource consumption increases despite efficiency gains, is referred to as the rebound effect.

A good example of this rebound effect can be illustrated by irrigation practices. Pfeiffer and Lin (2014) found that increases in the efficiency of irrigation techniques, implemented in Kansas between 1995 and 2005, have led to a significant increase in groundwater extraction. When more efficient irrigation systems came into use, farmers shifted to crops that are water intensive and high yielding and they changed their cultivation patterns. In this case, greater irrigation efficiency aggravated the region's problem of groundwater depletion (Pfeiffer and Li 2014).

To ensure that natural capital is preserved as much as possible, that resources yields are optimised and that system risks are minimised, the transition to a circular economy requires a whole systemic change reaching throughout value chains. Technological innovation is only part of the required transformation: innovative solutions in organizational thinking, civil society participation, financing methods and government policies are essential. The innovations necessary for a circular economy need to cover waste-minimizing designs, new business models and new recycling technologies as well as changes in consumer behaviour. For example, product design should ensure that products have a longer lifespan and are easy to maintain. Also, products can be designed in a modular way so that broken components can be replaced and repair is easy. When technological change is fast, it should be possible to upgrade products by changing only outdated components. At the end of the life of the product, it should be easy to disassemble it and to reuse or recycle its parts (Bocken et al. 2016).

17 This is an illustrative example of the concepts which have been developed to visualise the circular economy.

The circular economy is based on two important premises: at the company level, a closed loop business model that reaches through a company's value chain; and at the societal level, a re-design of the entire system to use resources efficiently and remove waste as a category. Thus, it goes beyond simple efficiency gains and encompasses the underlying consumption and production patterns of society. As such, it requires holistic life cycle systems thinking.

3. SHIFTING FROM LINEAR INDUSTRIAL SYSTEMS TO CIRCULAR ECONOMIES

So far, no nation has made much progress towards achieving a circular economy. Yet, quite a number of local or sectoral experiments have been undertaken to explore advancing towards circular economic implementation. These include closed loop industrial systems with lines of production designed to minimise waste and with outputs from one production line used as inputs for other processes. As individual firms are rarely sufficiently diversified to reuse the entirety of their outputs within the company, firms can cluster in geographic proximity to make the exchange of materials easier. The concept of industrial symbiosis describes networks of firms that share nontoxic by-products as resources to gain mutual eco-innovative benefits while reducing harmful influences on the environment and society (Tao 2017). In such networks, one company can use an output of another company that would otherwise have been wasted as an input to its own production process. Firms with such mutually complementary productions may co-invest in eco-industrial parks. While less sophisticated versions of eco-industrial parks only share facilities for pollution control, more sophisticated parks build on industrial symbiosis (UNIDO 2016). Denmark's industrial symbiosis complex at Kalundborg is widely recognised as a best practice case and its environmental and economic benefits are well documented (Jacobsen 2006).

What is even more important, however, is the application of closed cycles at the sector-wide or economy-wide level. Entire subsectors of the economy, such as the automotive or the consumer electronics industry, should be designed to maximise value creation from existing resource stocks and minimise waste. The following four practical examples illustrate these points. While the first three exemplify closed loop industrial systems, the example of a Korean national programme for reducing food waste in South Korea represents a more encompassing approach integrating public and private actors on the production as well as the consumption side.

ISKENDERUN BAY IN TURKEY: INDUSTRIAL SYMBIOSIS AT THE REGIONAL LEVEL

The Iskenderun Bay Industrial Symbiosis Programme established an industrial symbiosis network in the Iskenderun Bay region of Turkey. The programme is part of a wider national industrial symbiosis strategy and aims at increasing collaboration between regional companies to achieve environmental and economic improvements (International Synergies Ltd. 2014). The implementation phase lasted from 2011 to 2014. Within the industrial symbiosis network, 51 member companies from 28 different sectors work together to benefit from synergies (Alkaya et al. 2014).

An orange juice producer uses the waste heat of a lime producer to dry orange juice waste. As a result, 12,000 tons of waste pulp no longer go to landfills, but are turned into 1,400 tonnes of animal feed for reselling instead (International Synergies Ltd. 2014). A cooperation project of seven companies discovered that lint, a waste product from cottonseed production, could be used for the bioremediation of petroleum-polluted soils. Analyses found that apart from its strong absorptive capacity, the product also prevents petroleum from polluting the groundwater. Currently, a bio-products company is working on the commercialisation of the new product, which is expected to conserve 6,500 m^3 of water per year (Alkaya et al. 2014).

Full-scale implementation of ten symbiotic cooperative systems will lead to an estimated reduction in CO_2 emission of 36,700 tons annually and the redirection of 327,250 tons of solid waste from landfills to various forms of reuse. In financial terms, annual savings of US$ 6.37 million balance against total programme investments of nearly US$ 7 million, meaning the programme will pay off in just over a year (Alkaya et al. 2014). The success of the Iskenderun Bay Symbiosis Programme has led to the integration of Industrial Symbiosis into the 2014 to 2023 plans of 19 regional development agencies, some of which have already been initiated. Subsequently, industrial symbiosis was also included in the Ministry of Science, Industry and Technology's National Efficiency Policy (Alkaya et al. 2014).

YIXING ECONOMIC AND TECHNOLOGICAL DEVELOPMENT ZONE IN CHINA: INDUSTRIAL SYMBIOSIS AMONG 1,200 COMPANIES

The Yixing Economic and Technological Development Zone was established in 2006 to support the industrial development of green technologies (Chen 2017). While optoelectronic materials, photovoltaics and advanced equipment manufacturing are the leading industries, many types of industries are located in the zone, including textile, mechanical and chemical manufacturers. More than 1,200 companies now form a complex industrial symbiosis network with extensive cooperation (Li and Shi 2015).

The electric industry uses liquid argon, a by-product of nitrogen fertilizer production. The textile industry relies on acetic acid from citric acid production. The by-product of an inorganic chemical company, sodium nitrite, is used to produce organic compounds. Concrete, cement and other construction products are produced with fly ash and gypsum from coal burning. The thermal power plant uses dried sludge from the textile industry. Machinery components are produced with iron and steel scraps collected within the zone (Li and Shi 2015).

With the flourishing of industrial symbiosis came environmental problems. Due to water intensive and polluting industries, water quality became a severe concern in the area, so stringent water emission standards and strict governmental supervision were put in place. Two water treatment plants now recycle used water. In 2009, the total rate of water reuse was more than 90 per cent. The power and chemical industries use the most water by a significant margin, but recycle the majority of their discharge. However, the textile industry only recycled 10 per cent of its water, suggesting there is substantial need for analysis and innovative solutions (Li 2012).

COLLABORATION BETWEEN LOCAL GOVERNMENT AND THE PRIVATE SECTOR FOR INDUSTRIAL SYMBIOSIS IN TIANJIN, CHINA

The UK's National Industrial Symbiosis Programme, working through non-profit International Synergies, Ltd. (ISL), and the Tianjin Economic-Technological Development Area (TEDA) Administrative Commission in China have established the government-led collaborative ISL-TEDA industrial symbiosis project. The initiative for this project was derived from China's commitment to reduce its 2005 carbon intensity by 40 to 45 per cent by 2020 (Tao 2017; Watts 2009). The local government in Tianjin responded to this commitment with a project to build an industrial symbiosis match-up platform. Using this platform, factories can match their needs for input material with others' waste in the surrounding area. This approach is replicating the UK's National Industrial Symbiosis Programme (Wang et al. 2015).

The ISL-TEDA project achieved 99 synergies for industrial symbiosis, exceeding the project target of 80 matches (Tao 2017). It started with the local government's strong ambition to foster industrial symbiosis. The government took the lead and local private companies followed by implementing concrete action. It shows that private companies are willing to cooperate with governments when they can see economic benefits such as increased value added for their products, and social benefits such as improved reputation, and being long-listed for government procurement contracts. It illustrates the importance of a systemic approach from different actors to shift towards circularity.

A NATIONAL PROGRAMME FOR REDUCING FOOD WASTE IN SOUTH KOREA

To tackle a significant food waste problem in South Korea, several government ministries including the Ministry for Food, Agriculture, Forestry and Fisheries and the Ministry for Health, Welfare and Family Affairs have put in place a coordinated and comprehensive policy mix. The overall objective was to change food culture among the population, reduce waste and improve recycling. The measures include a National Masterplan on Food Waste Reduction to set the overall framework for implementation, a recycling programme requiring the collection of food waste in residential areas and catering industries, a landfill ban for food waste as well as voluntary agreements with the catering sector to encourage reduction measures in food waste and loss. For example, restaurants started offering eco-friendly menus and cut down the number of available small side-dishes. Cafeterias in public institutions organized a no-leftover-day once a week. Another interesting approach was the introduction of a volume-based food waste fee system. It requires households to pay a fee based on the amount of food waste they generate measured on a scale at the bottom of the waste bin. Monthly data serve as a basis for charging fees to households (Kim 2002). To promote recycling, the government has financed the development of public recycling facilities (Government of South Korea 2013). This mix of food waste reduction measures has had a great impact on raising consumer awareness and on the environment. The recycling rate of food waste has risen from 2 per cent in 1995 to 95 per cent in 2009 (Kim et al. 2013). Remaining food waste is now being turned into compost and livestock feed, as well as biomass and biofuels.

4. WHAT ARE THE SOCIAL AND ECONOMIC CO-BENEFITS OF GOING CIRCULAR?

The benefits of the circular economy are not only limited to improving the environment and related health problems. There are also compelling, immediate social and economic benefits for such a transition. These include employment gains and macro-economics.

EMPLOYMENT EFFECTS

The Ellen MacArthur Foundation (2013) estimates that in the EU manufacturing sector alone, net material costs of up to US$ 630 billion per year could be saved in a circular economy. Apart from significant environmental benefits, the social gains from increased employment are also substantial. In the UK manufacturing sector, remanufacturing–the rebuilding of outdated or broken products with updated components and modules–could potentially create an additional 310,000 to 320,000 jobs (Next Manufacturing Revolution 2013).

Waste collection, sorting and recycling create substantial sources of income for unskilled workers (Ellen MacArthur Foundation 2013). Some regions in industrialised countries and many developing countries do not yet have well-organized waste management infrastructure. In such conditions, a largely informal industry often provides jobs for waste scavengers, who search for recyclables in urban settlements and landfills that they can refurbish and resell. In Latin America between 500,000 and 4 million people work in this informal sector (Marello and Helwege 2014). The absence of centralized waste treatment has led to entrepreneurial activity. In some cities for example, waste pickers hold contracts with municipalities for their services, and waste picker cooperatives have developed complex business operations including the use of mechanisation for some tasks (Marello and Helwege 2014). Although the sector itself is still predominantly informal, 76 per cent of waste pickers in Africa, Asia and Latin America sell mainly to formal businesses, proving that there is demand for recycled goods (WIEGO 2014). In India, approximately 4.7 million tons of plastic bypass the public waste collection system every year and are sorted, cut, cleaned, pelletized and recycled by the informal sector to be returned to the economy (WBCSD 2016). Prospects for the circular economy in India are promising: efforts for a circular economy in construction, food and agriculture, as well as transport remanufacturing, could contribute US$ 624 billion by 2050, equivalent to 30 per cent of India's current GDP (Ellen MacArthur Foundation 2016c).

In the course of establishing better governmental recycling systems in developing countries, on the one hand, the informal waste picker community has to be taken into account. To fight poverty, it is essential not to destroy the livelihood of a large number of poor people, especially women, who represent the majority of waste pickers. On the other hand, aspects of pollution, workers' rights, health and safety and the elimination of child labour must be improved significantly. Therefore, public policy frameworks should be inclusive, clearly defining the role and contribution of waste pickers and their organizations, ensuring their access to protection, such as health and social programmes, and supporting safe practices. In Buenos Aires, Argentina, waste pickers were recognised as specialised waste management service providers and provided with official certificates (Gutberlet et al. 2017). This shows how governments can intervene to recognise and certify jobs in newly developing areas of the circular economy.

MACRO-ECONOMIC EFFECTS

Investing in circular economies reduces the import bill of resource-importing countries and can soften price shocks. In many resource-poor countries, natural resources–particularly refined oil and coal–account for a large share of their imports. Decreasing their domestic consumption thus frees up substantial resources. Moreover, world market prices of natural resource are often characterised by enormous price fluctuations that increase the importer's vulnerability. When China cut back the supply of aluminium in 2017, world market prices skyrocketed to a six-year high threatening the existence of aluminium-processing industries in import-dependent countries (Guoping et al. 2017). Collecting and processing waste aluminium, from electronics for instance, could greatly reduce the dependence on aluminium imports (Wilts 2016).

A possible repercussion involves effects on resource-exporting countries: Countries currently importing extracted resources that move towards circular economies aim to reduce their resource imports. That could have negative short-term consequences for resource-exporting developing nations, by lowering their expected revenues from export of raw resources (De Jong et al. 2016). Those exporting countries should develop mitigation strategies and diversify their economies away from resource extraction and export.

5. HOW TO OVERCOME BARRIERS AND PROMOTE CIRCULAR ECONOMIES

Despite the many exciting experiments and potential benefits, figures for global production and consumption show that no economy has achieved full circularity. Some promising achievements are worth mentioning, including exemplary regulations, such as the European Union's Ecodesign Directive and some comprehensive national recycling systems, such as Germany's Green Dot system (EU 2009; Baughan and Evale 2004). Yet overall, global production is still largely organized according to the unsustainable linear resource-to-waste logic, and lacks an organized, systemic approach to involve relevant actors to shift to circularity. What, then, is holding the circular economy back? This section looks at the barriers and what policymakers can do to promote circular economies.

SETTING GOALS AND DEFINING POLICIES FOR THE TRANSITION TO CIRCULARITY

To achieve circularity at an economy-wide scale and make it the norm—the new business-as-usual—the concept needs active government effort and strong coordination across various stakeholders as well as within industry itself. Many governments have shown great leadership in setting out ambitions for green growth. Their next challenge is implementation: learning how to achieve it in practical detail.

The transition to circularity needs to be recognised as a key principle of green industrial policy and mainstreamed in all relevant sector policies. An essential step is to have stakeholders–from different levels of government; the various players from the private sector, including investors and social entrepreneurs; and especially from civil society's cross generational and marginalized members–agree on overall national goals concerning resource use and pollution. These goals should be ambitious and broken down into sector-specific targets based on well-defined indicators. Japan, for example, uses three main indicators to measure its progress towards circularity: an indicator of resource productivity which measures material use as a share of total GDP; a cyclical usage indicator, quantifying the share of material reused of total material consumed by the economy; and an output indicator, which specifies how much waste is directed to landfills (Benton and Hazell 2015). The targets derived from these indicators then have to be further divided to give companies an objective for change. At the same time, this enables direct comparison of different companies and governmental programmes (Anbumozhi et al. 2016). The EU has mapped out an action plan for the circular economy that is supported by a concrete list of measures, divided by stages in product life cycle, with clear timelines. Located within the different stages are sub-strategies for the various industries and stakeholders involved in change (European Parliament 2016). These examples highlight the importance of a multi-stakeholder approach including private and public sectors of the society.

Measures to achieve the set objectives should ideally include a coherent mix of policies. Providing information, creating standards and labels that make the material footprint of product and processes transparent, educating consumers and encouraging voluntary initiatives can all help reduce wasteful resource consumption and environmental pollution. Yet massive change is unlikely to happen unless producers and consumers have strong economic incentives to adopt circularity. The policy mix will critically depend on the use of economic instruments, such as taxes, economic incentives and mandatory regulations, that can be combined in various ways. These are all important components of fiscal policy for environmental fiscal reform (Schlegelmilch et al. 2017, this volume).

NATIONAL REGULATIONS

On a national level, extended producer responsibility is the prime concept to guide industry towards more circularity, because it incentivises producers to improve their products to increase circularity. Additionally, waste collection charges, environmental taxes and mandatory deposit-refund systems can be used to steer behaviour and discourage unwanted practices.

The extended producer responsibility principle was first implemented in Germany with packaging legislation in 1992, then adopted by the European Union in 2008. Also in 2008, it was introduced in Korea with the Act on Resource Recycling of Electrical and Electronic Equipment and Vehicles (Ghisellini et al. 2016). Extended producer responsibility means that the costs of disposal and recovery of input materials should be borne by producers at the end of a product's lifetime. Companies can then either take products back or pay fees that cover the cost of recycling or waste management. Fees should vary, according to the treatment necessary for the input materials to be recovered. This would provide an incentive for producers to improve their product design (Wilts 2016). If companies use more resistant materials to make products reliable and durable, their payments for product disposal would be reduced (Bocken et al. 2016). Advanced disposal fees would also motivate producers to make their products repairable, so that the product is not immediately returned to the producer once it is damaged.

Governments can also introduce standards to make the market more transparent. They can request producers to provide information regarding repair and maintenance, and technical data for ease of repair should be standardised (RREUSE 2015). This would also encourage competition and reduce prices for repair works. If companies have to pay for disposal and input recovery, they will also be motivated to enhance recyclability. Fewer input materials will be used and the ones integrated will have a lower environmental impact, as hazardous materials are more difficult to be returned to the production process and should therefore entail a higher fee (Clark et al. 2009). In France, producers of vacuum cleaners with toxic flame retardant plastics pay a fee 20 per cent higher than for vacuum cleaners made from non-hazardous materials (European Environmental Bureau n.d.). Emerging countries are also moving forward with the implementation of extended producer responsibility. In 2016, Chile became the first country in Latin America to implement legislation by adopting the Recycling and Extended Producer Liability Law (Government of Chile 2016).

An extended producer responsibility approach is both an incentive for sustainable product design and for waste-to-resource solutions; but in itself it is not sufficient to make economies circular. Additional green industrial policies are needed, such as subsidies and tax-relief, enforcement of fines and punishment for illegal landfill dumping, infrastructure development for the collection of secondary material and sustainable public procurement.

Waste collection charges and environmental taxes, for example on landfill dumping and incineration, can help to reduce waste and at the same time provide funds for better recycling and treatment systems. In Russia, regulation used to limit the revenue generation from recycling. This prevented the emergence of a market for the treatment of municipal solid waste and led to treatment rates of only 10 per cent (IFC 2012). Revised legislation that no longer limits the revenue generation from recycling has been implemented to encourage newcomers to enter the market and increase transparency and competition (WasteTech 2017). In India, waste management is hampered by insufficient budgets for municipal authorities, which cannot afford to implement proper recycling systems (Kumar et al. 2017). Waste collection charges and environmental taxes could be used to improve the budget of environmental agencies and give them financial leeway for changes towards circularity.

For reusable and recyclable packaging, deposit-refund systems can be used to improve collection rates (European Environmental Bureau n.d.). In the US, many states have implemented a deposit-refund program for lead-acid batteries. A US$ 10 deposit for any battery sold has resulted in recycling rates of 97 per cent (Walls 2011).

INTERNATIONAL REGULATIONS

International regulation is also vital, because resources and waste are traded across borders, sometimes illegally. For electronic waste alone, between 60 and 90 per cent is estimated to be handled informally or unregistered. E-waste worth US$ 18.8 billion per year is illegally traded across borders and eventually dumped or unsafely recycled (Rucevska et al. 2015). Regional treaties and international agreements, such as the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and the Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa, provide frameworks on how to tackle these cross-border issues. They aim at limiting the export of toxic waste and therefore have direct implications for circular economies. These conventions, however, provide some exemptions that have been abused to bypass regulation at considerable scale (Khan 2016). Hence, additional national regulations and monitoring are often required to close existing loopholes. Under the Basel Convention, non-functioning electronic devices which need to be repaired, refurbished or upgraded can be defined as used electrical and electronic equipment intended for direct reuse. This category is exempted from the hazardous waste definition and can be traded across borders. National legislation complementing these agreements and treaties is necessary to provide further definitions and standards. In addition to being party to the Basel Convention, countries should define what kind of material can be exported or imported (Khan 2016). Regional regulation can be used to reap synergies and to avoid bureaucratic costs. In African states, national legislation complementing the Basel Convention is set to be implemented on a regional level. At the Pan-African Forum on E-waste in 2012, twenty African countries pledged unified action for regional regulation. They agreed to cooperate on the management of transboundary movements and the environmentally sound treatment of electronic waste (Pan-African Forum on E-waste 2012). Better regional regulation is also needed in the European Union where no uniform standard exists to define environmentally relevant characteristics of recycled materials. The national rules that have to be followed instead lead to additional bureaucratic costs (Barneveld et al. 2016).

SUPPORT NEW BUSINESS MODELS

To achieve a fully functioning circular economy, current business models need to change significantly. Most companies still base their sales model on increasing the number of products sold, regardless of their material consumption. From a sustainability perspective, more companies need to shift to new business models based on collecting, reusing, recycling, refurbishing or sharing products. New and innovative business models that aim at closing the circle are underway using a variety of tools.

Price signals: it is difficult to motivate factories to change their way of dumping waste, such as into landfills, when dumping does not cost much. For example, because of the extremely low landfill fee in China, about 7 per cent of the cost in the UK, the profit-driven factories tend to send waste directly to landfill, with little motivation to change (Tao 2017). Here, economic incentives could assign value to recycled resources and motivate companies, particularly recyclers, to set up facilities for recycling and establish a valuable business. In providing these incentives, the government should ensure that all actors in the value chain can benefit from them, to create shared value out of waste when it is treated as a resource.

Foster life cycle thinking: being unfamiliar with life cycle thinking tools reduces opportunities to have more viable solutions for resource efficiency. The application of a life cycle approach and perspective is helpful to keep a systems perspective and have scientifically informed policy decisions. It can be supported by tools, such as Life Cycle Assessment or Life Cycle Costing that integrate environmental costs in the evaluation of barriers and support the effective choice and use of policy instruments. A life cycle approach can support policymakers in identifying the key issues that need solutions and also in identifying whether specific policy proposals have any unintended consequences in other parts of the system. The approach displays existing trade-offs, and maps key stakeholders along the value chain to enable better decisions and choices. A life cycle or systems perspective helps to target all parts of the value chains of products such as product design; potential for repairing, refurbishing, reconditioning, remanufacturing; resources extraction; transport and infrastructure needs, including waste and recycling infrastructure, where many economic opportunities lie.

Investment and finance availability: informing entrepreneurs and small and medium enterprises about investors and potential partners who are willing to cooperatively start new business lines to close the cycle, partners that may be difficult to find. Establishment of specific credit lines for companies that want to innovate towards sustainability will be essential to spur new business models, especially those that require technology investment.

Two particular emerging service trends illustrate how new business models can enable the transition to a circular economy. The first is reverse logistics, with the goal of Maximising recovery of material used in production. In cooperation with manufacturing companies, reverse logistics facilitates the flow of products at the end of their lifetime from customers back to the industry. Received products then have to be disassembled. Their input materials can be recovered, or repaired to be sold in second markets.

Alternatively, the components can be remanufactured to re-enter the first market or to be sold to second markets (Govindan et al. 2015). The lack of fiscal and economic incentives in Brazil hampered implementation of reverse logistics under the National Solid Waste Policy. However, once reverse logistics became an important factor in competitiveness, companies started to invest in the necessary procedures (Finkler et al. 2017).

The second emerging service is product sharing. Instead of selling a product, a resource owner provides a customer with a product or service, while charging a transaction cost. Sharing decreases the volume of products that have to be manufactured to supply demand and increases the intensity of that one shared product's utility, so that it can be used to its full technical potential (Daunorienė et al. 2015). Experience from Korea shows that governmental support is important for such schemes, especially in the early phases of a sharing economy. Since 2012, Seoul's Metropolitan Government has pursued implementation of its Sharing City Initiative. Sharing programmes offer cars, books, music, tools, knowledge and skills, education, lodging and meeting facilities—all accessed through online platforms that help arrange matches. The initiative is designed to provide public services to citizens, especially those who are economically and socially disadvantaged, as the managers believe that the sharing economy can be instrumental in solving various urban problems. To trigger the diffusion and increase the number of participants, the Metropolitan Government distributed subsidies of US$ 500,000 to initiatives led by district governments and promoted public-social partnerships. In the course of the initiative, new business models were fostered by creating a legal framework in favour of the sharing economy to promote socially and environmentally beneficial activities (Moon 2017).

The underlying idea of using products without having to own them may involve a challenge for service providers: They have to make the initial investment in goods, but the flow of income starts later once usage fees are paid. To overcome this obstacle, financial instruments, such as green bonds, may be encouraged to enable circular business models (European Energy Agency 2014). Moreover, environmental fiscal reforms that shift the tax burden from labour to resource consumption and to pollution help to increase the competitiveness of circular business models that employ a large labour force (Wilts 2016; Schlegelmilch et al. 2017, this volume).

PROMOTE REGIONAL COOPERATION AND SPATIAL CLUSTERING

To promote regional cooperation and spatial clustering, governments can assign designated areas for eco-industrial parks. Policies and regulation on e-waste management, pollution prevention, energy saving and emission reduction as well as environmental taxes and fees on waste and pristine raw material can motivate companies to locate in eco-industrial parks and invest in industrial symbiosis networks. Additionally, guidelines for green infrastructure development and cleaner production promotion can serve as support (UNIDO 2016).

For designing eco-industrial parks and promoting industrial symbiosis, a high level of coordination is necessary to ensure that companies with complementary resource requirements invest and that companies throughout the supply chain receive a constant flow of the necessary inputs (Rahman et al. 2016). This is challenging, not least because information about companies' waste and by-products is not common knowledge and is treated with great secrecy (Fichtner et al. 2005). In some countries, the success of eco-industrial parks has been hampered by a lack of specific knowledge and coordination capacity of public authorities. For example, the Andhra Pradesh Special Economic Zone, India's first planned eco-industrial park, has attracted much less investment than anticipated, because many companies withdrew their proposed plans for establishing a unit within in the park (UNIDO 2016).

Still, government agencies can fund material flow studies to identify potential industrial symbiosis projects. Under the Eco-Industrial Park Programme in China, administrative committees oversee the development and management of eco-industrial parks. They give recommendations on how material and energy flows among tenants can be streamlined and which companies could be recruited to complement material flows while ensuring sufficient integrity of environmental infrastructures. Subsidies for small and medium-sized enterprises can make eco-industrial parks more diverse (Teh et al. 2014).

CONSUMER INVOLVEMENT

Civil society must be involved to achieve a circular economy. Recycling and waste reduction starts in the home and in schools, as does learning about sustainability choices. Consumer choices play an essential role in the circular economy, because they determine the quality and quantity of goods and services as well as the way those goods and services are produced. Goods and services that are produced in an environmentally sound and sustainable manner can be very competitive (Ambec 2017, this volume). Consumers are not driven by price alone, and distorted price signals that ignore the cost of environmental damage reduce consumers' opportunity to obtain sustainable products and services. Taxes and fees can be used to influence consumer behaviour. Reward schemes for returned items and deposit-refund systems can motivate consumers to return products at the end of their life to the producer or to a recycling facility (Forlin and Scholz 2017).

Many citizens, in addition, want to be informed about the origins and sustainability of products, services and processes. Information tools such as product sustainability information, awareness campaigns, or corporate sustainability reporting help consumers make informed choices. The efforts behind information-based instruments–environmental data collection and dissemination, development of indicators, environmental valuation, energy audits, education and training, eco-labelling or certification schemes, public disclosure of enterprises' sustainability performance–not only provide information and knowledge to the end consumer. They also complement and strengthen the effectiveness of other policy instruments, such as sustainable public procurement, environmental taxes, regulations, bans and restrictions that expedite transition to a circular economy.

Educational initiatives combined with product sustainability information further enable better consumption choices (Anastasio 2016). When designing educational programmes, policymakers need to address the gap between knowledge and action and to explore smart means of motivation: Even consumers with pro-environment attitudes do not always engage in behaviour that is environmentally responsible. The reason for this gap is that consumer behaviour can be influenced by rather irrational tendencies, such as cognitive biases and force of habit (Frederiks et al. 2015). Also, convenience makes a big difference for consumer decisions. Research has found that as convenience is improved in the design of recycling systems, participation rates increase (Samuelsen and Støyle 2016).

Increasing numbers of people, as citizens and consumers, are aware of the benefits of closed cycle, circular economies. Green consumerism organizations are emerging in many countries and communities demanding more durable, well-designed, sustainable products and processes. Policymakers can support such movements as important drivers of change towards circular economies.

6. CONCLUSION

To stay within planetary boundaries and to make today's industrial production sustainable, economies inevitably have to become circular. This chapter has shown that change comes with substantial benefits of increased economic stability, natural resource conservation, inclusion of socially disadvantaged groups, job creation and greener growth opportunities for all countries. It has also become clear that to promote circular economies, no single instrument can achieve the goal. Instead, a combination of coherent instruments is needed to fully optimise the environmental, social and economic benefits of circular economies. This policy mix would typically include regulations and financial incentives to promote circular product design, set up waste collection systems, support new business models and encourage change in consumer behaviour, among others. It requires a broad consensus among various actors, including the realignment of incentives.

So far, no single country has become fully circular. That means that no known pathway to achieving a fully circular economy exists. Although developing countries can benefit from some of the experience in developed economies, such as the technologies and implementation of successful waste collection and recycling systems, measures to promote circularity are far more comprehensive and must be tailored to realities in individual communities and countries. Any governmental plan for promoting the circular economy should include well-defined targets for each stakeholder group based on clear, measurable indicators and the mix of policy instruments selected should be coherent and socially inclusive. Any policy implementation will be successful only if there is alignment, coherence and stakeholder coordination.

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CHAPTER 9

TRADE AND INVESTMENT LAW AND GREEN INDUSTRIAL POLICY

Aaron Cosbey

1. INTRODUCTION

Other chapters in this book explore questions of what types of green industrial policies might work or have worked, and in what contexts. In this chapter we explore the ways in which such policies might be restricted by international trade and investment law.

The question is salient because international trade and investment play a fundamental role in sustainable development and trade is presented in the UN's Sustainable Development Goals as a means of implementation: "an engine for inclusive economic growth and poverty reduction [that] contributes to the promotion of sustainable development" (UN 2015: 29). As such, many traditional industrial policy tools are related to trade. At the same time, the body of international trade and investment law–contained in the General Agreement on Tariffs and Trade (GATT) and World Trade Organization (WTO) agreements, in regional and bilateral trade agreements, in bilateral investment treaties and in investment provisions of trade agreements–constitutes one of the most influential bodies of international law, with the strongest mechanisms of dispute settlement and enforcement.

The focus of this chapter is on describing where that body of international law conflicts with green industrial policies, by compiling a list of problematic policy areas. There are, as noted below, many other types of green industrial policy that governments might pursue that are not trade-related and are not restricted by trade and investment law. But these are not discussed at length.

This chapter first explores three cross-cutting issues that help elucidate the way in which trade and investment law relate to green industrial policy. This section will be optional for those with a solid understanding of trade law, but for others it will be an important introduction to the following discussion. That discussion assesses five of the most widely used types of policies that governments might employ to pursue green industrial policy, asking in each case how trade and investment law might treat them.

2. CROSS-CUTTING ISSUES

To fully understand the relationship of trade and investment law to various green industrial policy measures, it is necessary to review a few cross-cutting concepts:

- How is WTO law related to non-multilateral trade and investment law? This is important because it means nothing to simply say that trade law prohibits or allows a given policy; trade law exists at the WTO multilateral level as well as in regional and bilateral agreements; and there is trade-related investment law at both those levels as well as in dedicated investment agreements. The different bodies of law contain different rights and obligations.
- How does WTO dispute settlement interpret existing law? In many cases it is difficult to say with authority which policies are legal or not, and it is important to understand why that is.
- How do the exceptions work in trade and investment law and how might they be applied in the context of green industrial policy? Exceptions are important to this discussion, since a number of green industrial policy measures seem to be in conflict with trade law obligations. But in some cases they can be saved by exceptions.

2.1. RELATIONSHIP BETWEEN WTO LAW AND NON-MULTILATERAL AGREEMENTS

The WTO body of trade and investment law is a collection of legal agreements among the 164 members of the WTO, spanning various trade and investment-related subjects. One of the most relevant to green industrial policy is the GATT, but there are also more specialised agreements covering how governments should create and implement trade-related measures such as subsidies, government procurement, standards and labelling, intellectual property rights, investment measures and others. For the most part, all WTO members are bound by the obligations of all agreements, but there are a few that have been agreed among a sub-set of members only–called plurilateral agreements. Members that have acceded to the WTO since it succeeded the GATT in 1995 are bound by the terms of their individual accession agreements, which may involve additional obligations.

WTO members are also bound by commitments they may have made in non-multilateral settings, for example in regional trade agreements and bilateral investment treaties, and it is important to understand how the bodies of law interact.

Regional trade agreements will not typically set out obligations that are less onerous than those found in WTO law since, no matter what the regional trade agreement parties agree among themselves, they are still bound by their obligations to other WTO members. Whether or not these agreements explicitly refer to it, WTO law still binds the parties. Regional trade agreements may clarify what the regional trade agreement parties understand to be WTO law, where there are some doubts. For example, the Mexico-Panama free trade agreement clarifies that the WTO exceptions for measures designed to protect human, animal, or plant life or health will cover environmental measures, though the word environment does not appear in the original WTO text (Mexico-Panama Free Trade Agreement 2014, Article 19.2(1)). This is not an alteration of WTO law, but merely a declaration of mutual understanding as to how that law should be interpreted.

On other issues regional trade agreements go beyond WTO law in setting out Parties' obligations. In the Canada-EU Comprehensive Economic and Trade Agreement, for example (Article 8.5(1)(f)), Canada and the EU prohibit the use of technology transfer requirements as a condition for investing in their territory—a commitment not found in the WTO's Agreement on Trade-Related Investment Measures. Similarly, it is typical in regional trade agreements for the parties to agree to intellectual property right provisions that are stronger than those found in the WTO's Agreement on Trade-Related Intellectual Property, such as longer terms for patent protection. In such cases the so-called WTO-plus provisions typically apply only between the parties.[18]

In the area of investment, WTO law is contained in the Agreement on Trade-Related Investment Measures, which has relatively light obligations. Non-multilateral agreements in this area are found in bilateral investment treaties and in the investment chapters of regional trade agreements. The investment law in such agreements is almost all WTO-plus. As with trade-related provisions, WTO law is still in force and obligations in such agreements will only apply between the parties.

The analysis below focuses primarily on WTO law when discussing trade-related law, since most of the relevant non-multilateral commitments are similar to those found in the WTO. When discussing investment-related law, the analysis focuses primarily on bilateral investment treaties and the investment chapters of regional trade agreements. When the analysis departs from these parameters, this is noted.

2.2. INTERPRETATION AND APPLICATION OF TRADE AND INVESTMENT LAW

Green industrial policy efforts can conflict with trade and investment law. There are several important caveats that apply when discussing the potential conflicts. First, the law is not usually spelled out to the level of detail that would allow it to be obvious how it applies in any given situation; were that possible, there would be few disputes. Rather, the applicable law must be interpreted in the context of each case, taking into account the specifics of the measures in question. Moreover, some aspects of WTO law call for judgment in interpretation: What do 'reasonable' or 'disproportionately large' mean in a specific context? And there are often dissenting interpretations issued on such questions by the different authorities: in the case of the WTO, panellists or appellate body members. As such, it is not always possible to say unequivocally that a certain type of policy is or is not prohibited by WTO law. There is no principle of precedent in WTO law, but in practice the principle is well respected.

Blanket statements become even more difficult in the area of investment law. Ad hoc arbitral panels interpret investment law and, while they will be conscious of previous awards, they have been known to issue widely divergent interpretations on essentially similar questions of law (Jones 2011; Ortino 2012; Nilsson and Englesson 2013). In WTO disputes the final interpreter of the law is the standing Appellate Body that tends to adhere strongly to case law.

It should also be noted that most WTO members arguably have many WTO-illegal measures in place. The fact or probability of illegality only comes into play when some other WTO member formally complains about those measures, possibly taking the issue beyond consultations to dispute settlement. The decision to do so is not taken lightly by any government, and suspected non-conforming measures are often simply

18 Some regional trade agreements' (RTA) commitments apply more broadly. For example, a change in patent protection terms would affect all a country's trading partners.

ignored as not damaging enough to warrant the cost and political friction engendered by dispute settlement proceedings. No such political or public interest filter exists in the case of investment law, where a private investor has the right to initiate binding arbitration with the host government, as investor-state dispute settlement.

2.3. EXCEPTIONS TO TRADE LAW

Some forms of green industrial policy measures are likely to breach WTO or investment law obligations. For several areas of trade law this is not the end of the story. Some agreements include carefully described exceptions that cover agreed objectives, including environmental ones such as conservation of exhaustible resources and protection of human, animal or plant life or health (GATT, Article XX; General Agreement on Trade in Services (GATS), Article XIV; Agreement on Trade-Related Investment Measures (TRIMs), Article 3; Agreement on Government Procurement (AGP), Article III). GATT Article XX serves as a sort of template model for such exceptions:

> Subject to the requirement that such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade, nothing in this Agreement shall be construed to prevent the adoption or enforcement by any contracting party of measures: ...
>
> (b) necessary to protect human, animal or plant life or health; ...
>
> (g) relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption; ...

Some of the agreements discussed here have these sorts of exceptions: the WTO and regional trade provisions on trade in goods, trade in services, trade-related investment measures and government procurement. Others do not, such as the WTO Agreement on Subsidies and Countervailing Measures, subsidy provisions of regional trade agreements and bilateral investment treaties.

Governments will find it difficult, if not impossible, to successfully use the general exceptions in trade law to 'save' non-conforming green industrial policy measures. In GATT Article XX, the chapeau paragraph's requirements that the measures not be unjustifiable discrimination or a disguised restriction on international trade are caveats to ensure that the measures to be saved are only focused on achieving the specified objectives, in this case environmental objectives. However, by definition green industrial policy measures aim to achieve both environmental objectives and economic objectives, and exceptions to the law are definitely not meant to save the latter.

In other words, if a green industrial policy measure is seeking the exception status of GATT Article XX (b) or (g), the objective of the measure will have to match the environmental criteria in those sub-paragraphs—and this should be straightforward. The measure will be aimed at preserving the environment. But the elements of the measure that simultaneously seek to promote industrial development will also need to be justified as environmental in nature, or face rejection under the chapeau text.

So a measure discriminating in favour of a domestic green sector would have to provide some environmental rationale for that discrimination. If foreign competitors produce environmental goods or services more efficiently, there is no such rationale at least in the short run: it would actually be better for the environment to use foreign manufactured environmental goods and services. Because they are cheaper, such imported goods would yield more environmental benefit per dollar spent.

Cosbey and Mavroidis (2014) have suggested that such an environmental rationale might exist, describing an 'environmental Bastable test'. The Bastable test asks whether the total costs of an industrial policy measure are outweighed by the value of all the future benefits that the measure might produce. The cost and benefits would be calculated as present discounted values of the stream of future costs and benefits. If the balance is positive, the measure is judged worthwhile. This is strictly a national economic cost-benefit calculation.

The environmental Bastable test, on the other hand, would be a global assessment and would look at total environmental costs and benefits. It would count as costs the lost environmental benefits from slower deployment of the technologies, and against this it would balance the future environmental benefits. Those benefits would materialize only if the policy succeeded in creating new innovators and competitors in the environmental technology space.

So if it could be convincingly argued that creating new firms in a green sector ultimately resulted in environmental gains—that a measure passed the environmental Bastable test—then a green industrial policy measure might pass GATT Article XX (b) or (g). But this would be difficult. The environmental Bastable test, like the original test, is mostly a heuristic device and impractical to use as a benchmark. The success or failure of any given green industrial measure is unpredictable and not easily quantified for the purposes of environmental cost benefit analysis. Given the sceptical audience such an argument would likely have in the WTO dispute settlement system, its chances of success are not good.

GATT's Article XVIII provides another set of exceptions to GATT rules, for balance of payments and industrial policy purposes that apply to parties whose economies "can only support low standards of living and are in the early stages of development". There has never been case law to clarify exactly which countries are covered by this description.

These industrial policy exceptions are found in GATT Article XVIII sections A and C. Section A allows a covered member to withdraw or modify a scheduled GATT concession, to raise a tariff, to "promote the establishment of a particular industry with a view to raising the general standard of living of its people." Such a move must be preceded by notice to other members and negotiations with any member that is substantially affected to agree on compensatory adjustment—likely the lowering of tariffs in other areas of interest to its partners. It is technically possible but very difficult for such an effort to proceed even when a member is unsuccessful in getting negotiated agreement with its partners. This would require agreement from the general membership, including any countries that had withheld bilateral agreement.

Section C allows a covered member to take other sorts of unspecified measures aimed at the same objective, even where they conflict with most GATT obligations. Kuntze and Moerenhout (2014) argue that this might include feed-in tariffs with domestic content requirements, for example. The measures qualifying for exception status under GATT XVIII section C would have to be notified to other WTO members, and if the members agree that there is no more GATT-consistent manner to achieve the same objectives, then the measure can proceed. However even if no such agreement can be reached, the notifying member can, after 90 days, implement the notified measure. Affected members can request negotiations on compensation.

There has been limited case law to interpret Article XVIII, with only two cases and those concerning balance of payments provisions, not the industrial policy clauses (WTO 1999; WTO 2002a; WTO 2002b). As such it remains to be seen how free a WTO member might be to take advantage of what seems to be a useful exception. Neither of the two balance of payments cases was decided in favour of the implementing country. It is not obvious which countries might benefit. For example, China is a developing country member of the WTO, but it is unclear whether it could be characterized as 'in the early stages of development'. It is also unclear whether the member would be required to demonstrate that the proposed measures would actually raise the general standard of living of their people—something that might be difficult in the case of domestic content requirements. And of course the requirements for negotiations on compensation to affected members may make the proposition less viable.

3. LEGALITY OF TRADE- AND INVESTMENT-RELATED MEASURES

This section explores the following types of policies and measures, all of which might be employed as elements of green industrial policy:

- Tariffs
- Subsidies
- Performance requirements
- Service sector limitations
- Government procurement
- State-owned enterprises
- Competition policy.

This is not an exhaustive list of the policies that aim to further green industrial policy, but it covers the most commonly used policies that have trade and investment legal implications.

3.1. TARIFFS

Under certain conditions, tariff protection for infant industries may result in welfare gains for the implementing economy (Greenwald and Stiglitz 2006). Tariffs are the most straightforward tool of industrial policy. They were featured heavily in strategies for import substitution industrialisation pursued by mostly Latin American economies between the 1930s and 1980s with a mixed record of success (Baer 1972). Tariff protection for industrialisation purposes also served a number of today's developed economies throughout their history of industrialisation (Baer 1972; Chang 2002).

As well as simple tariff walls for infant industry protection, tariff levels can be manipulated to favour a greater degree of processing domestically. Tariff escalation is the practice of setting tariffs increasingly higher for more heavily processed goods.

But there are limited opportunities to use tariffs in these ways. Commitments to bind import tariffs at agreed levels are the most basic of the GATT obligations. Each member has a schedule of commitments that outline the maximum tariff they may apply to various goods (GATT, Article II:1). This maximum is the bound rate. Within the space afforded by that rate, countries are free to vary their tariffs for any purpose and the resulting tariff is called the applied rate. But the progressive liberalisation embodied in the GATT and WTO processes has seen average tariffs drop from an estimated 22 per cent pre-GATT in 1947 (Bown and Irwin 2015) to 1.5 per cent in 2014 (World Bank 2017), meaning that space is limited for most goods and most countries.

3.2. SUBSIDIES

Subsidies may be the most widespread tool of industrial policy, and of green industrial policy more specifically. They can take many forms, including:

- cash grants
- land grants
- preferential tax treatment
- concessional loans
- loan guarantees
- export credit
- price support
- mandated purchase regimes, such as feed-in tariffs
- public research and development
- provision of dedicated infrastructure, not of use to the general public.

The WTO definition of subsidies is used in this analysis. In the WTO Subsidies and Countervailing Measures (SCM) Agreement's Article 1, that definition requires that there be either some form of price support or a financial contribution by a government or public body. A financial contribution can take several forms:

- direct transfer of funds
- non-collection of government revenue otherwise due, such as taxes
- provision of goods and services, other than general infrastructure, or purchase of goods.

Two final threshold tests of a subsidy in WTO law are that the price support or financial contribution must confer some benefit on the recipient, for example, purchase of goods should be at higher than market rates, and that the support or contribution is specific. Specificity in this case means that it is targeted at, or primarily benefits, a particular enterprise, industry, or group of enterprises or industries. According to the Agreement on Subsidies and Countervailing Measures' Article 2, specificity can be found where there is explicit direction in the measure for a subsidy to go to a narrow group, or can be found where the measure makes no such provisions but the final effect is such that specific groups benefit.

There are two types of subsidies in WTO law: prohibited and actionable. A prohibited subsidy is conditioned on domestic content requirements or on some form of export performance. If a subsidy is found to be prohibited, there is no need to demonstrate specificity–it is assumed. Prohibited subsidies breach WTO commitments and must be removed. Actionable subsidies are all other measures that fit the WTO definition of a subsidy. Actionable simply means they are open to complaint. To be found WTO-illegal, actionable subsidies must be shown to be specific, and to cause adverse economic effects for the complainant's producers.

The SCM's provisions constitute limits on the types of green industrial policy support that countries might offer via subsidies. The most obvious limitation is against the use of prohibited subsidies. Countries may not impose domestic content requirements as a condition for the receipt of a subsidy. A number of countries have sought to build up their capacity in the renewable energy space with such subsidies. Canada was taken to WTO dispute settlement over the province of Ontario's use of domestic content requirement-linked subsidies, as feed-in tariffs, to build up domestic solar and wind sectors (WTO 2013); the EU was taken to consultations by China for similar measures in Greece and Italy (WTO 2012); and the US listed domestic content requirement-linked subsidies as part of their complaint against the Indian National Solar Mission, though ultimately it did not pursue the subsidy angle (WTO 2016).

The other element of prohibited subsidies is a link to export performance. This means that governments cannot make subsidies conditional on a firm's achieving a certain level of exports or create tax exemptions that only apply to exported goods, for example. Many green industrial policy efforts involve an expectation that the supported forms will contribute to the domestic economy through export activities. And best practice in industrial policy involves assessing success and cutting off support to unsuccessful firms, which could be structured in such a way as to constitute a conditional link to export performance. So this aspect of subsidy law poses significant obstacles to some types of green industrial policy. Note, however, that least developed countries and certain low-income countries are exempted from the strictures on export-linked subsidies (Agreement on Subsidies and Countervailing Measures, Article 27.2). That exemption applies only until they have reached export competitiveness–a threshold that is not defined (Agreement on Subsidies and Countervailing Measures, Article 27.5).

Export credit might also be considered a prohibited subsidy. Export credit can be either the provision of a loan to an exporter or the guarantee or insurance of such a loan, referred to as 'pure cover support'. It can be used to help domestic firms achieve successful export market penetration, spanning the cash-flow gap between shipment and actual payment. The Agreement on Subsidies and Countervailing Measures includes disciplines on both types of export credit. The loans themselves cannot be made at rates of interest below the rates the government has had to pay for the funds or the rates they would have to pay if they borrowed commercially. The pure cover support cannot be made at premium rates that would result in the support programme running at a financial loss.[19]

Moving beyond prohibited to actionable subsidies enters a 'grey zone of uncertainty' since, among other things, governments cannot predict whether their measures are specific or whether they will cause adverse effects for foreign producers (Charnovitz 2014). Guidance in this zone must consider first whether a given green industrial measure might be considered a subsidy, including the consideration of specificity, and then whether it could cause adverse effects.

It was noted above that feed-in tariffs had been the subject of a number of disputes. When conditioned on domestic content requirements, such tariffs will almost certainly be considered prohibited subsidies. But without the domestic content requirements, they fall into the grey zone of uncertainty. The first question is whether they are in fact subsidies. In the Canadian renewable energy dispute described above, the Panel ruled that they were, but the Appellate Body overturned that ruling, arguing that it was necessary to compare the prices offered under feed-in tariffs to prices offered in a hypothetical competitive market for renewables—not to the prices of conventional electricity—to gauge whether the feed-in tariffs were too high (WTO 2013, paragraph 5.246). Being unable to identify such a hypothetical market, the Appellate Body was unable to complete the analysis, and unable to find that the feed-in tariffs were subsidies. In the end the answer will depend strongly on the details of the feed-in tariff regime in question. Among other things, the higher the rates paid, the more likely the measure will be considered a subsidy. If feed-in tariffs are considered to be subsidies, the second question is whether they cause adverse effects, in this case to foreign producers of renewable electricity. Renewable electricity being rarely traded, and almost universally subsidised, this second step is unlikely to occur. As such, feed-in tariffs without domestic content requirements attached are probably WTO-legal, and are used in more than 100 jurisdictions worldwide, in 75 national level schemes and 35 sub-national level schemes (REN21 2016:109).

Such feed-in tariffs may serve green industrial policy objectives by facilitating a green structural transformation. But since they lack the domestic content requirements they may not be as effective at fostering domestic sector development. That said, feed-in tariffs without domestic content requirements could still have some beneficial effects on domestic firms, especially if they are employed as one element in a suite of green industrial policy measures that target those firms. Indeed, they were used in that way by Germany in its *Energiewende* (Lütkenhorst and Pegels 2014; Pegels 2017, this volume).

19 Item (k) paragraph 2 carves out any export credit that is covered by and conforming to "an international undertaking on export credit" – a clear reference to the OECD Arrangement on Guidelines for Officially Supported Export Credit. But this Arrangement has failed to evolve beyond a gentlemen's agreement and so has no legal coverage of the sort envisioned in item (k) paragraph 2. As such, the carve out is not in effect.

Subsidies can also be used to support research and development, a type of support that is central to green industrial policy efforts worldwide. Research and development subsidies produced strong success in the US with such breakthrough information technologies as the integrated circuit and the microprocessor and they contributed to the establishment of Silicon Valley as a centre of excellence (Leslie 2000; Mazzucato 2013). These subsidies fall squarely in the grey zone of uncertain legal status under WTO rules: while they may be actionable subsidies, it is inherently difficult to assess whether they meet the test of causing injury to foreign producers. In one of the largest subsidy disputes ever handled in the WTO, the US complained of a number of aspects of the EU's support for Airbus' production of large civil aircraft, including funding for research and technology development. The Panel in that case found that the funding was indeed a subsidy, and that it caused adverse effects to Boeing, its US-based competitor. The Appellate Body agreed that a subsidy existed, but overturned the ruling that it caused adverse effects, arguing that the Panel had not shown a direct link between the support and specific technologies in Airbus products that demonstrably gave it a competitive advantage (WTO 2011a, paragraph 1407).

The most obvious point to draw from this is that, as noted above, it is not straightforward to predict what green industrial policy measures will run afoul of WTO law; on this specific question the Panel and the Appellate Body disagreed. More important, the Appellate Body's ruling seems to set a fairly high bar for finding adverse effects from research and development subsidies. However in a subsequent case, a complaint by the EU against US subsidies to Boeing, the Appellate Body agreed with the Panel that research and development subsidies "contributed in a genuine and substantial way to Boeing's development of technologies for the 787" and as such caused adverse effects (WTO 2011b, paragraph 1012). Ultimately the legality of research and development subsidies is highly context-specific, leaving an uncomfortable degree of uncertainty for governments.

In the SCM Agreement there was a third category of subsidies in addition to prohibited and actionable: non-actionable (Agreement on Subsidies and Countervailing Measures, Art.8). These were subsidies that served objectives that the members acknowledged as so important that they would be allowed to stand even if they did cause adverse effects. These included subsidies for research and development, as well as subsidies for a limited category of support to meet the costs of environmental regulations. But the provisions were time-limited, and when they failed to be renewed in 1999 they expired. A number of authors have suggested reviving and modifying the non-actionable category to cover subsidies with environmental aims (Hufbauer et al. 2009; Cottier 2011; Rubini 2012; Charnovitz 2014; Shadikhodjaev 2015).

One of the most prevalent green industrial policy tools is tax policy, with preferences of various types being accorded to favoured sectors and firms in an effort to encourage the development of linkages in the economy, to encourage export orientation, or to address various market failures by lowering costs (Schlegelmilch et al. 2017, this volume). Export-linked subsidies are prohibited. Subsidies aimed at encouraging linkages, for example tax preferences to firms that transfer technology or hire local workers, are considered under performance requirements–a separate category of policy tools and measures.

For other types of tax preferences, the law of the WTO is that they are a subsidy if they represent revenue forgone that is otherwise due (Agreement on Subsidies and Countervailing Measures, Art. 1.1(a)(1)(ii)). So if a tax preference is an exception to the normal tax practice for a specific firm or sector, it is a subsidy. Of course, determining what is normal practice is often difficult. Determining adverse effects is not straightforward either, but the Panel in an EU complaint against Boeing's research and development seemed to set the bar low, using 'commonsense reasoning' to infer that lower taxes allowed Boeing to price at lower levels than would otherwise have been possible (WTO 2011b, paragraph 7.1820).

Tax policy can also be used punitively, as a tool to deliberately target sectors that should be phased out or altered as part of a green structural transformation. Pollution charges are a common tool of environmental policy, and carbon taxes in particular are becoming more so. This sort of disruptive use of green industrial policy tools could be used to phase out sectors such as fossil fuels (Cosbey et al. 2017, this volume). This use of tax policy is not limited by trade law, which is more concerned with states according favourable treatment to domestic firms and sectors.

Several other types of potential green industrial policy measures are very likely candidates for conflicts with WTO subsidy law:

- direct grants of land to a firm, where such grants are not generally available to other firms/sectors

- construction of infrastructure that will only be used by the firm or sector, such as a railway to transport minerals from mine site to port
- mandated floor prices for the sector's products, where these exceed what would prevail in a competitive market.

Subsidies to services are not disciplined under WTO law, so green industrial policy measures that involve such subsidies are available to governments. Governments could, for example, subsidise domestic environmental engineering services to build up their capacity to export.

There are a few types of measures commonly labelled subsidies that are not constrained by WTO law. In general, subsidies to consumers fit this mould, since the subsidies will not discriminate between green goods from foreign and domestic producers; consumers can use the subsidies to purchase either, unless there are aspects of the law that prevent such free choice. This will mean no adverse effects.

The under-pricing of environmental externalities is sometimes labelled subsidy, as when a government imposes weak environmental regulations on its firms, giving them a competitive advantage. This would not constitute a subsidy under the definition of the Agreement on Subsidies and Countervailing Measures.

3.3. PERFORMANCE REQUIREMENTS

A performance requirement is a condition that investors must meet to establish or operate a business, or to obtain some advantage offered by the host nation. Performance requirements could include conditions to:

- export a certain percentage of total sales, or total production
- enter into joint venture arrangements with domestic partners
- transfer or share technology
- source a certain amount of inputs locally
- expend a certain amount on research and development
- hire a certain number or percentage of local employees.

Governments may impose performance requirements as mandatory measures. Governments may also provide investors with fiscal incentives or other advantages in exchange for businesses' compliance with the performance requirements. The purpose of most of these requirements is to better exploit the potential of foreign direct investment to build up domestic capacity in specific sectors or firms.

The WTO's Agreement on Trade-Related Investment Measures prohibits two types of performance requirements: requirements to purchase domestic content and requirements regarding certain export links and balance of payments. The former was the point of law on which Canada lost its case on renewable energy: its feed-in tariffs were deemed prohibited investment measures because they conditioned investors' price premiums on the use of domestic content (WTO 2013).

The prohibitions in the Agreement on Trade-Related Investment Measures are augmented by obligations in some international investment agreements–a group of agreements that Nikièma (2014) calls the 'growing minority.' Housed in investment chapters of regional trade agreements or in bilateral investment treaties, most modern agreements signed by the US, Canada and some Asian nations also prohibit requirements to transfer technology and to supply an identified international market exclusively from the host country.

The commitments in these agreements, even where they mirror those found in the WTO, arguably have more deterring force. WTO commitments are enforced through state-to-state dispute settlement, which states will only initiate if they pass a significant threshold of public interest. Commitments in international investment agreements, on the other hand, are enforced through investor-state dispute settlement, which is triggered by the investor based on a much narrower calculus. As well, a loss in the WTO dispute settlement system entails the withdrawal of the disputed measure, while a loss in the investor-state dispute settlement system involves financial penalties ranging as high as billions of dollars.[20]

There is still a great deal of scope for the use of other forms of performance requirements even by Parties to these WTO-plus agreements. That scope is clarified, for example, in the investment chapter of the US-Korea Free Trade Agreement [2012] Article 11.8(3)(a):

> Nothing in paragraph 2 [which prohibits certain performance requirements] shall be construed to prevent a Party from conditioning the receipt or continued receipt of an advantage, in connection with an investment

20 The largest award to date, awarded to Yukos under the Energy Charter Treaty over its expropriation by Russia, totalled US$ 50 billion (Brauch 2014). It was later set aside on jurisdictional grounds.

in its territory of an investor of a Party or of a non-Party, on compliance with a requirement to locate production, supply a service, train or employ workers, construct or expand particular facilities, or carry out research and development, in its territory.

That said, there is always some uncertainty. The Tribunal for a North American Free Trade Agreement (NAFTA) investment dispute ruled that new requirements for research and development spending and education and training spending were prohibited performance requirements (Vis-Dunbar 2013; ICSID 2013). This ruling, however, was not related to NAFTA prohibitions against requirements for research and development, but relied on the prohibition against domestic content requirements, interpreting the new rules as requirements for local spending.

3.4. SERVICE SECTOR LIMITATIONS

The WTO's General Agreement on Trade in Services governs trade in services at the multilateral level. Services are roughly defined as those purchased items that one cannot drop on one's foot: banking, tourism, telecommunications or real estate services, for instance. Environmental services include environmental engineering, environmental remediation, eco-tourism, and the services of actors such as energy service companies, wind/solar farm developers and residential installers of renewable energy systems. Kommerskollegium (2014) argues strongly that without an underpinning of green services, there would be few green goods.

WTO members each have a schedule of commitments in the GATS that describe what kind of treatment they will offer to foreign service-providers. That treatment will vary from sector to sector, and there is no expectation that a member make commitments in all sectors. There are two types of commitments possible:

- commitment to treat foreign service suppliers no less favourably than domestic ones, or national treatment
- openness to investment in the sector, or market access commitments.

It is possible to qualify the commitments in any way the members wishes. A member might, for example, commit to offer market access to foreign service-providers in the banking sector only to those above a certain level of capitalisation.

Commitments will also specify what mode of service delivery is being covered:

- Mode 1: from a foreign country to the member.
- Mode 2: consumed by member citizens in the foreign country.
- Mode 3: delivered by a foreign investor establishing a commercial presence in the member country.
- Mode 4: by means of foreign nationals entering the member country to work as service providers.

Mode 3 is of particular interest in the context of green industrial policy and trade law. The GATS specifies a number of restrictions to the sort of regulations members may use to limit foreign presence of service providers (GATS, Article XVI.2). Members may not maintain or adopt:

a. limitations on the number of service suppliers whether in the form of numerical quotas, monopolies, exclusive service suppliers or the requirements of an economic needs test;
b. limitations on the total value of service transactions or assets in the form of numerical quotas or the requirement of an economic needs test;
c. limitations on the total number of service operations or on the total quantity of service output expressed in terms of designated numerical units in the form of quotas or the requirement of an economic needs test;
d. limitations on the total number of natural persons that may be employed in a particular service sector or that a service supplier may employ and who are necessary for, and directly related to, the supply of a specific service in the form of numerical quotas or the requirement of an economic needs test;
e. measures which restrict or require specific types of legal entity or joint venture through which a service supplier may supply a service; and
f. limitations on the participation of foreign capital in terms of maximum percentage limit on foreign shareholding or the total value of individual or aggregate foreign investment.

These obligations effectively constrain the ability of governments to foster domestic capacity by limiting or putting conditions on entry of service sector investors. In the GATS, these obligations only apply to sectors in which members have made some sort of commitments. However these limitations appear in a number of recent regional trade agreements (US-Korea Free Trade Agreement [2012], Article 12.4; Trans-Pacific Partnership Agreement [2015], Article 10.5; Korea-Vietnam

Free Trade Agreement [2015]; Article 8.4; US-Central America Free Trade Agreement [2004], Article 11.4), mostly signed by the US, where they are horizontal commitments made with respect to all sectors–a much more extensive restriction.

As of early 2017 there are negotiations ongoing among WTO members for a plurilateral Trade in Services Agreement. With the EU counting as one, the 23 members involved are responsible for over 70 per cent of global trade in services. These talks have dragged on longer than expected—currently amounting to over 20 negotiating rounds—and may not be finalized any time soon. While the drafts of the negotiating text are classified, leaked text as of June 2016 shows draft provisions on localisation that would go well beyond what is in the GATS, including proposed prohibitions on requirements for:

- a service provider's board members to be nationals
- purchase of a set amount of domestic content, or preferences for local goods
- technology transfer
- the hiring of a certain number or percentage of nationals
- expenditure on research and development in country.

On some of these provisions there is disagreement among the negotiating members, so it is impossible to say what the final text might contain. It does seem clear that any final outcome is likely to restrict the ability of governments to use green industrial policy in the context of trade in services.

3.5. GOVERNMENT PROCUREMENT

Government procurement can be an important tool of green industrial policy. This can be significant as government procurement in 2010 averaged 10 to 15 per cent of GDP globally (Anderson et al. 2011). The scale of demand means that this sort of assistance can be used to help firms attain viable scale and learn by doing under difficult start-up conditions (Geroski 1990). This is particularly important for newly commercialized goods such as non-solar non-wind renewable energy technologies, new low-carbon transport and battery technologies, and the like.

Procurement for green industrial policy goes beyond simply purchasing green goods. Procurement of services, and in particular services such as research and development, is a central part of some governments' strategies for industrial development. This has long been the case in the aerospace sector, for example, where US and European governments award contracts for research and development in areas of particular interest to their domestic firms (Eliasson 2010).

The WTO strictures on government procurement are contained in a plurilateral deal, the Agreement on Government Procurement (GPA). As of October 2017 the Agreement covers 47 of the WTO's 165 members, with another nine members in the process of accession. Membership is strongly tilted toward more developed economies, with only six of the parties from outside the World Bank high-income classification, and three of those being parties due to their EU membership (WTO 2017).

The GPA offers significant scope for governments to procure environmentally superior goods and services. Article X.6 makes it clear that Parties are allowed to craft their technical specifications in such a way as to take environmental considerations into account. And the Agreement contains an exception clause similar to GATT's Article XX, allowing for measures necessary to protect plant, animal or human life or health (Agreement on Government Procurement, Article III.2).

But while the scope for environmentally motivated procurement exists, the scope for using those purchases to foster the development of domestic capacity is extremely limited. The exceptions clause makes it clear that the discrimination in question cannot be a disguised restriction on international trade, and must be justifiable. Other articles in the agreement make it clear that the drafters' intent is such that building domestic capacity would not be a justifiable form of discrimination. Article IV.6 prohibits the use of offsets in the procurement practice, offsets being defined in Article 1 paragraph (l) as:

> ...any condition or undertaking that encourages local development or improves a Party's balance-of-payments accounts, such as the use of domestic content, the licensing of technology, investment, counter-trade and similar action or requirement.

Further, Article IV.2 mandates that there should be no discrimination against locally established suppliers on the basis of nationality, or on the basis of the origin of the goods and services the supplier might offer.

There are certain exceptions provided for developing countries that accede to the Agreement on Government Procurement. Among these are that during an individually negotiated transition period, such parties may adopt price preferences for national suppliers or those of other developing countries. But for the majority of developing countries, not having acceded to the Agreement, there are no obligations that would prevent them from using procurement as a tool to promote domestic enterprises.

The catch in some cases will be how procurement is defined; it cannot be for the purposes of commercial resale (Agreement on Government Procurement, Article II.2(a)(ii)). This was one of the legal downfalls of India in its WTO dispute with the US over its Jawaharlal Nehru National Solar Mission (WTO 2016). India awarded solar power developers with long-term power purchase agreements, but eligibility hinged on the use of mandated amounts of domestic content. India argued that the purchase of electricity from the developers amounts to government procurement. That argument was rejected, as the electricity purchased was to be resold on a commercial basis to Indian consumers.

Had India or Canada succeeded in arguing that their purchases were for the purpose of government procurement, they would have benefited from a GATT carve-out for government procurement measures (GATT, Article III.8(a)). That carve-out exempts government procurement from the GATT strictures of national treatment, and thereby also exempts it from the obligations found in the Trade-Related Investment Measures Agreement, under which both Canada and India lost their cases.[21] GATT Article II.8(a) is a broad carve-out that benefits any member that has not acceded to the Agreement on Government Procurement, allowing almost unlimited scope for the exercise of procurement as green industrial policy.

It was noted above that some governments use procurement of research services as industrial policy support, and here too the definition of procurement is central. The US argued that its contracts for research services with Boeing were government procurement and therefore not covered under the Agreement on Subsidies and Countervailing Measures, which the US argued does not cover purchases of services. The Panel disagreed with the claim as government procurement, arguing that the contracted work was for the sole benefit of Boeing, the contractor, and that therefore the contracts amounted to direct transfer of funds (WTO 2011b, paragraphs 7.978–7.1027). The Appellate Body overturned that reasoning, characterizing the contracts as more akin to equity infusions in a joint venture, equity infusions being one type of subsidy as per the WTO definition, wherein the return on the government's equity was expected to come in the form of useful scientific and technical information, discoveries and data. Either way, what the US characterized as government procurement of research services was ultimately found instead to be a subsidy (WTO 2011b).

3.6. STATE-OWNED ENTERPRISES

Governments often use public ownership of enterprises, whether full or partial ownership, to further industrial policy objectives. As of 2012, state-owned enterprises included the world's 13 biggest oil firms and biggest natural gas company, and their penetration in emerging market sectors was considerable: energy at more than 60 per cent state-owned, utilities at more than 50 per cent, telecoms at more than 30 per cent and finance at more than 30 per cent (Wooldridge 2012).

Governments are able to push such firms to achieve public policy objectives, as opposed to narrowly defined commercial objectives. State-owned enterprises might, for example, be pressured to source from local suppliers or hire and train local employees. Most or all of their research and development will be domestically conducted, leading to potential spillover benefits and development of domestic sectoral expertise. State-owned enterprises also may have greater capacity and appetite than private sector actors to invest in ventures that require substantial capital outlays and/or risky ventures that aim to produce breakthrough technologies (Ciuriak and Singh 2015). State-owned enterprises as tools of green industrial policy are not widespread; their reach is mostly confined to extractive sectors and utilities. But they could become green policy tools in the future, should governments decide to develop national firms in green sectors.

There is broad scope within the WTO for such policy choices (Singh and Jose 2016). GATT's Article XVII on State Trading Enterprises obliges members that establish state-owned enterprises to ensure that they operate as commercial enterprises in their purchases and sales, not discriminating between national and international suppliers or customers, for example. This does limit the potential use of local purchasing preferences, but does not limit the establishment of

21 The TRIMS Agreement's prohibitions on domestic content requirement are in effect a clarification of what is prohibited under GATT's Article III on national treatment.

state-owned enterprises. The not-yet-ratified Trans-Pacific Partnership goes much further than WTO law, for example with signatories obliged to not cause injury to other signatories' industries by providing direct or indirect non-commercial assistance to their state-owned enterprises (Trans-Pacific Partnership Agreement, Article 17.6). These provisions, which resemble subsidy law, are not found in other regional trade agreements but their inclusion in the Trans-Pacific Partnership may signal a trend.

3.7. COMPETITION POLICY

Competition policy is a framework of legislation and institutions that aims to ensure competition among economic actors. The objectives of competition policy vary with the national and historical context (Motta 2004), but many of them focus on a common set of problems raised by a lack of competition, including:

- distribution of wealth from consumers to monopolistic firms, with a resulting overall loss of welfare
- reduced incentives for firms to innovate and seek efficiencies, with possible environmental impacts
- abuse of dominance in the market, including acting to reduce the ability of new firms to enter the market.

Competition policy usually consists of a national competition law and institutions to enforce the law and advocate for competitiveness among the various related ministries. One of the major tasks of any national competition body is to scrutinise mergers and acquisitions to determine whether they meet competition-related public interest criteria.

In some cases industrial policy can increase competition among firms in a national economy, but the intersection of competition law, industrial policy and trade law lies in the practice of granting exemptions from competition law for industrial policy purposes. The history of industrial policy in Korea, for example, involves state encouragement of mergers and cartels to achieve the economies of scale and experience necessary to compete at the international level (Amsden 1989). Taiwan similarly encouraged mergers, particularly in sectors facing difficulties (Wade 1990). Cosbey and Mann (2014) discuss the widespread use of industrial policy in the context of the mining sector to create national champions– domestic firms that dominate the economic landscape in their respective sectors. These are examples of a common practice in competition policy–the introduction of broader public policy objectives that may ultimately see competition lessened to achieve non-competition-related objectives.

There is no conflict between trade law and this sort of selective enforcement of competition policy. There is no discipline in WTO law that obliges members to enact or enforce competition policy, though there has been discussion on the subject for many years (Evenett 2003). There is a standing Working Group on the Interaction between Trade and Competition Policy that reports to the WTO's General Council. The Trans-Pacific Partnership breaks new ground for trade agreements in addressing competition policy, but even that agreement allows significant leeway to national governments to exempt the application of competition law for public policy reasons, asking only for consistency and transparency, and providing no dispute settlement mechanism (Trans-Pacific Partnership Agreement 2015, chapter 16).

3.8. CONCLUSIONS

This section assesses whether there are areas of trade and investment law that constrain the use of green industrial policy (Table 9.1). In many cases there do exist such constraints. For example, tariff policy is strongly constrained by bound tariff rate commitments, subsidies and performance requirements are conditional on domestic content requirements and export performance are prohibited. As well, governments that are party to the Agreement on Government Procurement cannot use offsets or discriminate in favour of domestic suppliers in their procurement.

Where clear constraints do not exist, government policy may be discouraged by uncertainty. Governments will be understandably reluctant to embark on programmes of green industrial policy that take them into what we have called the grey zone of uncertainty of trade and investment law, such as actionable subsidies for research and development and other purposes, or the use of GATT's Article XVIII exceptions for developing countries.

That said, uncertainty could also be seen as policy space. Most governments have laws that are probably in breach of their trade and investment obligations and this is only a problem when another country complains about them. Formal complaints are costly, in terms of both political capital and financial and human resources. They will be launched only when those costs are perceived as justified by significant adverse effects and when the odds of winning are sufficiently high. They may also be considered when domestic political concerns demand it, and this may happen even in the face of low odds. Small economies are less likely to be challenged, since their export streams tend to be less significant. The time that it takes to finally come to resolution of a complaint can also be seen as policy space. In rare cases, a decade might pass before the WTO's dispute mechanism renders final judgement on a measure, its appeal, and subsequent complaints over non-compliance with judgments. By that time a green industrial policy measure may have achieved its goals.

On the other hand, the mere threat of WTO disputes is often enough to steer small developing country governments away from grey zone measures, since the costs of managing a dispute are high and expert resources are scarce. In the case of non-WTO investment agreements, there is a very different calculus for launching a complaint. This can be done by a private firm without consideration of wider political concerns, and there are now funding models that encourage speculative forays into arbitration (Honlet 2015).

Table 9.1: Summary: Legality of Trade and Investment Measures

	Status	Conditions	Applicable Law	Notes
Protective tariffs	unrestricted (conditions)	only permitted within boundaries set by bound tariffs	WTO - GATT	bound tariffs are increasingly low - not much room for policy
Subsidies				
linked to exports	prohibited		WTO - SCM	But allowed for LDCs
conditional on LCR	prohibited		WTO - SCM, WTO - TRIMs	
Feed-in tariffs	unrestricted (conditions)	only when not accompanied by LCR conditions	WTO - SCM	these may be actionable subsidies, but would likely never be challenged
Support for R&D		cannot cause adverse effectes for foreign competitors	WTO - SCM	
Preferential tax treatment				
subsidy removal (disruptive)	unrestricted			for example, fossil fuel subsidy reform
subsidies to services	unrestricted			
consumer subsidies	unrestricted			
Export credit		cannot be offered on non-market terms	WTO - SCM	
Performance requirements				
local content	prohibited		WTO - TRIMs	
technology transfer				allowed in WTO; prohibited in a few international investment agreements
joint venture				allowed in WTO; prohibited in a few international investment agreements
employment targets	unrestricted			
R&D expenditure	unrestricted			But have been interpreted by a recent Tribunal as local content requirements
training of locals	unrestricted			

	Status	Conditions	Applicable Law	Notes
Service sector requirements				
quantitative restrictions on providers	prohibited		WTO - GATS, many RTAs	
limits on foreign shareholding	prohibited		WTO - GATS, many RTAs	
domestic content	unrestricted			But possibly slated for prohibition in TISA
technology transfer	unrestricted			But possibly slated for prohibition in TISA
R&D expenditure	unrestricted			But possibly slated for prohibition in TISA
hiring of locals	unrestricted			But possibly slated for prohibition in TISA
Government procurement				Highly restricted in GPA, but not all WTO members are parties to GPA
State-owned enterprises	unrestricted (conditions)	no nationality-based discrimination in purchases or sales	WTO - GATT Article XVII	
Exemptions from competition policy	unrestricted			
Punitive environmental taxes, charges	unrestricted			E.g., carbon taxes

That said, there are of course green industrial policy options still open to governments that are interested in promoting domestic green sectors. Feed-in tariffs can be used as part of a broader suite of measures, as long as they do not contain domestic content requirements, for example. Performance requirements for training of staff are also acceptable. Those governments that are not party to the GPA still retain broad scope for using government procurement as green industrial policy. There are, moreover, a number of types of green industrial policy to which trade and investment law do not apply, such as science and education policies designed to build up domestic capacity, general infrastructure investment, funded demonstration projects, legal reform to encourage investment, and so on.

There are also a number of exceptions available to developing countries, such as the ability of least developed counties to use export-contingent subsidies, although they may lack the fiscal resources to make that exception meaningful, and the as-yet untested industrial policy exceptions available through GATT Article XVIII.

But ultimately it is clear that trade and investment law imposes substantial obstacles for many types of green industrial policy. This is to be expected. Trade and investment law have as core principles the commitment to non-discrimination between foreign and domestic producers and investors, and industrial policy is ultimately about benefiting the latter, usually at the expense of the former. For this reason domestic content requirements are so clearly and powerfully prohibited, for example. For this reason consumer subsidies to purchase green goods are probably acceptable while subsidies to domestic producers of those same goods are not. As a general rule, trade and investment law restricts 'vertical' policies–those that discriminate between foreign and domestic firms in specific sectors. In contrast, 'horizontal' policies, such as generic infrastructure investment, legal reforms, regulatory strengthening, science and education policies, tend not to be affected.

4. CONCLUDING THOUGHTS

This analysis has found major impediments for certain types of green industrial policies in trade and investment law. It bears asking the question: is this a problem? The answer depends, among other things, on an assessment of whether the green industrial policies in question are actually effective at achieving their stated objectives: enhancing environmental quality while contributing to domestic economic wellbeing by building up producers of green goods and services. Bahar et al. (2013) argue strongly that domestic content requirements are ineffective, wasting scarce dollars that could be more effectively spent on renewable energy technology dissemination and reducing global public welfare. If they are correct, and this is a general truth, then it is not a problem for domestic content requirements to be constrained by trade and investment law. If, on the other hand, domestic content requirements can be effective, then the limits imposed by trade and investment law are problematic. Johnson (2013), for example, puts forward clear recommendations to policymakers for successful use of domestic content requirements, based on an analysis of India's National Solar Mission.

Assessing the potential effectiveness of the various measures surveyed here is beyond the scope of this paper, but the question needs to be asked if we are to judge the propriety of trade and investment law impediments to green industrial policy, and to consider possible reforms.

A useful heuristic proposed earlier in this paper is the environmental Bastable test. For any given green industrial policy intervention, does the present value of the environmental impacts of the measure, in terms of long-term increased competition and innovation in a global green sector, exceed the present value of the environmental costs–usually in terms of short-term higher prices for environmental goods and services, and their consequent curtailed dissemination? It is noted above that this framework is useful for thinking about the problem, but less useful in calculating the value of any specific measure.

It is also useful to bear in mind one of the key differences between traditional industrial policy and green industrial policy. In the former context, the benefits vest almost exclusively in the implementing country, and the costs are born by foreign producers–a traditional mercantilist outcome. In the latter context, the costs are much the same, but the benefits may be much different. If the green industrial policy is successful in fostering new globally competitive entrants in green sectors with global impacts, such as the renewable energy sector, then the benefits will be felt globally. That is, not only will the implementing country improve environmental outcomes directly via its own structural transformation, but it will also foster indirect global environmental improvement by lowering the costs, or improving the effectiveness, of green goods and services. If the goods and services in question address a significant global environmental problem, such as climate change, those global benefits will also be significant.

This is an important consideration because the laws on trade and investment are founded in public welfare economics. If the restricted policies can indeed be effectively used in ways that would increase global public welfare, then there is a strong case for the reform of those restrictions. In the context of the multilateral rules, however, a strong case may not be enough, at least in the short term. The room for new negotiations in the WTO is highly restricted by the inability to conclude the Doha Round of trade negotiations.

Given the imperative importance of the two challenges that green industrial policy addresses, environment and development, it is urgent to find authoritative answers to the question of effectiveness. Of course it is impossible to say in the abstract whether certain policies will be effective. The specific context is decisive, as are the details of implementation. It is likely that for many of the policies surveyed here the answer is that they are sometimes effective. The question then for trade and investment policymakers is whether it is appropriate to prohibit policies that can be effectively utilised, even if it is clear that success will be elusive. The alternatives to such a prohibition are reform of the law to guide policies toward effectiveness as mandatory sunset provisions, for example, or opening wide the doors to green industrial policy with the clear understanding that states can and will get it wrong, to the detriment of their trading partners. The crucial global public interest element to green industrial policy, as opposed to traditional industrial policy, should have an influence in the final balance point among the many deciding factors in the mix.

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PART 4:
COUNTRY EXPERIENCES

CHAPTER 10

RENEWABLE ENERGY AS A TRIGGER FOR INDUSTRIAL DEVELOPMENT IN MOROCCO

Georgeta Vidican Auktor

1. MOROCCO: A REGIONAL PLAYER IN THE RENEWABLE ENERGY SECTOR[22]

The Middle East and North Africa (MENA) region has been in the spotlight regarding investments in renewable energy technologies. Both national governments and international donors have started to view renewables as an important solution for the energy and development challenges in the region. Their interest has also been fuelled by increasing evidence that investments in renewable energy technologies can open the path to inclusive and green growth, through job creation, private sector development, greening of the industrial sector and environmental sustainability (UNEP 2011; World Bank 2012; IRENA 2013).

Within the region, Morocco stands out as a particularly interesting case. First, the country imported more than 95 per cent of its energy in 2011, and its energy demand is expected to triple by 2030 (MEMEE 2011). This strong dependence on imports places Morocco in a very precarious energy and financial situation over the next decades. At the same time, due to its geographical location, Morocco benefits from vast renewable energy resources that could be exploited to provide energy beyond the country's domestic needs. Second, as in other countries of the region, Morocco suffers from a high unemployment rate, especially among the educated youth–a situation that calls for private sector development with a focus on job creation. Finally, Morocco's manufacturing base is relatively low, industrial competitiveness is deficient and entrepreneurship is limited. However, promising signs of technological upgrading in some sectors, including automotive and aeronautics, suggest a new momentum in the private sector that could lead to new opportunities (Hahn and Vidican Auktor 2017).

To respond to these challenges, the Moroccan government has engaged in an ambitious and highly dynamic process of developing the renewable energy sector. In a short period of time, Morocco has gained a reputation as the most promising destination for solar and wind energy investment in the MENA region. What distinguishes Morocco from other countries is its commitment to linking solar and wind electricity generation projects to industrial development, employment creation and competitiveness more generally, even if only small steps in this direction have been made so far. The overall approach embraced by Morocco appears to be more comprehensive than that of other countries in the region. In times of major turmoil across the MENA region, efforts made by the Moroccan government to maintain political stability have reinforced the country's status as the upcoming market for solar and wind energy. The high level of investment that already materialised for the first large-scale renewable energy plants underlines this positive outlook. All these factors, if adequately channelled, will contribute to positioning Morocco as a regional player in this emerging sector.

In light of these early developments, this chapter aims to capture not only the strategic steps taken by the government to deploy renewable energy technologies but, more importantly, to delve into how opportunities for entering new sectors and developing skills have been exploited and how they could be further harnessed in the future. In particular, the chapter explores how the government uses industrial policy to localize parts of production for renewable power plants and support the development of a local industry. The chapter also examines how policymakers balance high-tech concentrated solar power plants and low-tech rooftop solar thermal and photovoltaic aspects of the renewable energy strategy. The chapter also explains how the strategy pursues targeted skills development–from technical vocational education and training to higher education–to increase competitiveness. So far, progress has been slow due to several internal and external factors, but effort has been consistent. Thus, assessing these early steps and distilling lessons learned can only contribute to solidifying further developments.

The chapter is structured in the following way: It starts by highlighting why green industrial policy is crucial for Morocco in the context of pressing challenges to development and energy security. It then discusses three important elements of such an industrial policy—market creation, supply side measures, and an integrated strategy for industrial development—with regard to existing steps taken at the government and private sector level and the potential barriers to achieving the set objectives. The chapter ends with some considerations on how to capitalise on these early steps.

22 The empirical part of this chapter originates primarily from in-depth interviews conducted in 2012 with a large set of stakeholders involved in the solar energy sector development in Morocco (see Vidican et al. 2013). The data has been updated through subsequent research.

2. GREEN INDUSTRIAL POLICY: A NECESSITY FOR MOROCCO

Under the leadership of King Mohammed VI, Morocco has proven to be one of the most stable economies in the MENA region. This stability, however, could become fragile if insecurity and political unrest in neighbouring countries intensifies. Morocco's late industrialisation process and access to European markets following the signing of comprehensive trade agreements enabled development of traditional sectors such as agriculture and textiles, as well as new sectors such as automotive and aeronautics. In spite of such progress, the country faces deep challenges to deliver much needed development outcomes in terms of jobs and reduced inequality (AfDB 2011). Morocco realizes that it also needs to identify global markets in which it may have competitive advantages.

The high level of unemployment among the educated youth is a persistent problem in Morocco, and across the entire MENA region, as is the low rate of female labour force participation (Nabli and Chamblou 2004). Unemployment in Morocco reached 9.5 per cent in 2015; but it is much higher among educated youth between 15 and 24 years old, at 22 per cent (Haut Commissariat au Plan du Maroc 2015). Coupled with high shares of employment in the informal sector–ranging from 15 to 82 per cent, depending on concept definitions–and underemployment, the labour market problem in Morocco is magnified (Angel-Urdinola and Tanabe 2012; Saif 2013). Moreover, Morocco's relative competitiveness has decreased over the past few years, mostly due to a worsening performance with respect to business sophistication, innovation, and labour market efficiency (WEF 2015). In response, the government enacted extensive reforms to boost economic growth, reduce inequality, attract investment and increase efficiency in government spending (IMF 2011). Three main initiatives stand out: the National Energy Strategy; the Moroccan Innovation Initiative; and the revitalization of the national industrial development strategy, *le Pacte National Pour l'Emergence Industrielle* and its later revision *le Plan d'Accélération Industrielle du Maroc*.

While each of these initiatives is discussed in greater detail in the following sections, it is noteworthy to draw attention to a few distinctive aspects. Morocco has become highly committed to diversifying its energy mix and thus reducing its vulnerability to changes in global fuel prices. This is mainly due to its dependence on energy imports and its wealth in renewable energy sources through high solar irradiation and wind speed along the coast. Importantly, the government understood that high investments in the clean energy sector must also deliver socio-economic outcomes. Thus, what emerged from these initiatives are the seeds of a comprehensive policy aiming to advance structural change and competitiveness on the basis of low-carbon, resource efficient technologies. These actions, in effect, align with the definition this volume uses for green industrial policy. Even if the Moroccan government has not labelled their interventions as a green industrial policy, the direction is clear: developing a market for renewable energy technologies; supporting local companies to enter this new sector; implementing environmental rules and standards in other sectors, such as agriculture and housing, to green the economy and thus aiming for an integrated industrial development strategy. Morocco's commitment to green the economy is also illustrated by other national strategies that were initiated since 2010—on Sustainable Development, on Environmental Protection, on Improvements of the Environment, and the Green Morocco Plan for Agriculture. That commitment is also demonstrated by the country's active engagement in the UN Framework Convention on Climate Change (UNFCCC) COP21 in 2015 and its decision to host UNFCCC COP22 in Marrakesh in November 2016. While progress with respect to industrial development in the sphere of renewable energy has not been as fast as observers may have preferred, advancement has been steadfast.

3. EARLY STEPS TOWARDS RENEWABLE ENERGY DEVELOPMENT

The renewable energy strategy was initially framed to strictly address energy security concerns. In the process, however, Morocco's government recognised the opportunities that a green industrial policy would offer for its economy and for its energy sector in particular. In 2008, ambitious renewable energy targets were set, aimed at diversifying the energy mix. The link to industrial policy was also soon articulated. Although value chain localisation remains limited, Morocco's strategy remains progressive with regards to investments, deployment, and value creation at regional level and also among other developing countries. This section elaborates Morocco's early steps with respect to renewable energy market creation, supply side measures, and strategic steps towards linking energy and industrial policy, with a focus on the solar energy sector. Challenges towards achieving policy objectives are also highlighted and discussed.

3.1. MARKET CREATION

To address the very high and persistent dependency on energy imports, in 2009 the government elaborated the National Energy Strategy aiming to supply 42 per cent of electricity generation with 2,000 MW from solar, 2,000 MW from wind, and 2,000 MW from hydro sources, thus harnessing the vast renewable energy resources present in Morocco. By 2017, Morocco expected to have 36 per cent of installed capacity coming from renewable sources: 1,800 MW from hydroelectric energy, 800 MW from wind, and 180 MW from solar. Prior to the COP21 climate negotiations in Paris, the government renewed its renewable energy targets to 52 per cent by 2030 (MEMEE 2015). Once these targets are achieved it is expected that by 2030 3,440 MW of solar photovoltaic, 1,300 MW of concentrated solar power, and 4,997 MW of wind energy will be installed (MEMEE 2015).

The *Plan Solaire*, the strategy for the solar energy sector, was developed to provide a road map for achieving the solar energy targets by constructing five large solar power plants for a total of 2,000 MW. When completed in 2018, the Ouarzazate Solar Complex of 500 MW will be the largest solar farm in Africa. The first part of this complex, 'Noor I' of 160 MW is operational since February 2016, developed by a consortium of foreign firms, while `Noor II' has already been commissioned.

The types of technologies targeted for these investments are primarily concentrated solar power and a smaller share of solar photovoltaic. The objective is to increase the share of solar energy in total electric capacity to 15 per cent by 2020 and to reduce emissions by 3.7 million tonnes of CO_2 per year (Invest in Morocco 2016). Along with the *Plan Solaire*, new laws and organizations were created and large external investments, as well as development assistance, were engaged. Donors, such as the World Bank and the European Investment Bank, saw vast opportunities arising from supporting the large-scale deployment of concentrated solar power technologies in North Africa. In particular, cost reductions for this more expensive clean technology could be captured as well as the cumulative learning from applying it, benefiting the solar industry worldwide. Moreover, exploring the extent to which social and economic benefits could be generated locally–in terms of jobs and local manufacturing, for example–was also high on the agenda of development cooperation partners (World Bank 2012).

From the Moroccan side, the creation of a favourable legal framework has been an important step to enabling the emergence of a market for renewable energy. In particular, Law 13-09 allowed medium and high-voltage projects to access the electricity network and opened up competition in this new market. This law also permits projects with capacities of maximum 50 MW to be built and operated by private enterprises. Low-voltage projects, those of less than 2 MW, would encourage a market for solar rooftop electricity generation projects to emerge. They have been discussed since 2015 and further amendments of the current law are still expected (Daouda 2016).

To ensure the implementation of the *Plan Solaire* the government committed US$ 9 billion and created the Energy Development Fund with an equivalent of US$ 1 billion mostly based on donations from the Kingdom of Saudi Arabia, the United Arab Emirates and a contribution from the Hassan II Fund for Economic and Social Development (Invest in Morocco 2016). It also created the *Société d'Investissements Energétique*, endorsed by the state and the Hassan II Fund, to support investments in small and medium scale renewable energy projects.

A critical development has been the creation of a separate agency in 2010, the Moroccan Agency for Solar Energy (MASEN), specifically tasked with project development and implementation of the *Plan Solaire*. More recently, following an instruction of King Mohammed VI in December 2015, MASEN's role was extended to the entire renewable energy sector, changing its formal name to the Moroccan Agency for Sustainable Energy, and seeking to coordinate closely with the national utility *Office National de l' Électricité et de l'Eau Potable* on the implementation of both solar and wind energy projects (Schinke and Klawitter 2016). MASEN started by organizing the competitive bidding projects for the solar plants, coordinating the combination of grants and loans by multilateral and bilateral donors. MASEN has played an important role in the development of the solar sector, due to its high standards, professionalism and competencies, in terms of engaging both with international partners and with local policymakers and stakeholders. Through its integrated approach to the development of solar energy projects–with a focus on electricity production, industrial integration, training, and research and development–MASEN also sought to harness the co-benefits from power generation projects. However, its overarching power and stretch in terms of its mission, beyond project development to foster industrial development and research and development, could weaken the initiatives of other actors in the larger system (Vidican 2015). By capturing a wide range of activities under their powerful organizational umbrella, it is likely that much-needed resources for more specialised actors could be diverted. More cooperation across various stakeholders might magnify the positive outcomes. To overcome this risk, MASEN should seek to further enhance its cooperation with other local actors and to develop local competencies across the renewable energy sector (Vidican 2015).

While these developments enabled the implementation of the first projects, several factors prevented further market expansion beyond the landmark 160 MW Noor I, which had been mostly funded by bilateral and multilateral donors. These factors include lack of sufficiently targeted incentives for small and medium enterprises, a missing regulatory framework for distributed generation and small-scale projects such as rooftop photovoltaics, and not clearly specifying the type of technologies targeted by the *Plan Solaire* (Vidican et al. 2013). For instance, a feed-in tariff is lacking and net-metering schemes have been under discussion for a long time. To reach a resolution, at the end of 2015 the government adopted Law 58–15, which modifies and complements the existing 13-09, introducing a net metering scheme for solar and wind power plants, but only for those connected to the high-voltage grid (Daouda 2016). A result of this law is that private renewable power investors will be able to sell 20 per cent of their annual production to the grid. It is expected that the law will be extended to also include the middle and low-voltage projects, including solar photovoltaic installations.

Creating a market for small independent and household electricity producers could have significant implications for private sector development in the short and medium term. Distributed generation using solar photovoltaic has high potential for local small and medium enterprises to engage in the sector not only in installation and maintenance, but also in manufacturing parts and components for the system.[23] A major hurdle emerges exactly from the institutional structure that is often prescribed to developing countries, specifically unbundling of the energy system. In Morocco's larger urban centers, most electricity is distributed through private entities, called *Régies*. Fearing loss of customers, these entities have so far blocked regulatory advancement that would support distributed electricity generation through solar photovoltaics.

Morocco does have previous experience with solar energy technologies. In 1996 the government initiated a project for improving rural electrification, called the *Programme d'Électrification Rurale Globale* (PERG). This programme increased the rural electrification rate from 15 per cent in 1996 to 98 per cent in 2010 (RCREEE 2010: 19). Ten per cent of households, especially in off-grid rural areas, received decentralized electrification by installing a solar photovoltaic system on their roofs. Up to 2011, around 60,000 of these systems had been installed with a total capacity of 4 MW (PWMSP 2011: 10; RCREEE 2010: 19). This component of the PERG aimed to expand the use of renewable energy and enable local enterprises to gain experience with the production and installation of small photovoltaic systems (Vidican et al. 2012). Indeed, most Moroccan enterprises active in the solar energy sector have their origins in this early initiative. Estimates of jobs created as a

23 The importance of a large market for incentivising private investments in manufacturing is illustrated by the wind energy sector in Morocco, where projects of more than 850 MW have been commissioned. As a result, Siemens Wind Power and Renewables is building a manufacturing plant for blades, committing an investment of EUR 100 million expected to generate 1,200 direct and indirect jobs (Innovant 2016).

result of the PERG are rare, but evidence suggests that 13,000 direct and indirect jobs were created by 2006 and 30 subcontractors, especially system installers, benefited from the rural electrification programme (George 2002; Allali 2011a).

Solar water heaters, a simple but effective technology, are currently deployed below capacity in Morocco. Yet, an integrated solar water heater and photovoltaic support programme was created in 2002. Although a number of companies emerged in manufacturing, installation and servicing, as a result of a programme called *PROMASOL*, the market did not develop significantly. Problems in implementation, quality and servicing prevented large-scale deployment. More recently, financial support mechanisms and technical assistance were established to help entrepreneurs and to trigger investment projects in local manufacturing of solar water heaters (Allali 2011b). In 2012 a new programme, called Shemsi, was created to capture this untapped potential. The objectives are to install 1.35 million m^2 of solar water heaters by 2020, reduce the national energy bill by saving on imported and highly subsidised butane gas, create jobs by supporting local producers of solar water heaters and improve product quality standards (ADEREE 2016). To avoid the pitfalls of the earlier programme, Shemsi has made significant effort in improving the quality of the water heaters, through labelling and certification programmes, accreditation of installers and developing product standards (ADEREE 2016).

To foster further market creation for solar technologies, a particularly important effort is the Moroccan authorities' focus on linking solar energy applications to other sectors, such as housing with rooftop photovoltaic systems and solar water heaters and agriculture with solar water pumps. The *Agence Nationale pour le Développement des Energies Renouvelables et de l'Efficacité Energétique* (ADEREE) initiated collaborations with the Ministry of Agriculture and Ministry of Housing and Urban Development to integrate renewable energy technologies in new projects. Such initiatives are critical to introducing low-carbon technologies into the Moroccan society more broadly. To address the social development goals, an important objective is the creation of new housing units for a growing population. If these new housing units are fitted with solar water heater and photovoltaic systems, an important market for small and medium enterprises in this sector can emerge. Similarly, water pumping for irrigation in the agriculture sector is currently performed using engines powered by subsidised butane gas. Yet, once the market distorting subsidies are removed, a market for solar water pumps can emerge, with similar gradual but positive effects on the small and medium enterprise sector in Morocco. Under increasing budgetary pressures, the Moroccan government made major progress in reducing subsidies, especially since 2014, with the goal of completely eliminating consumer subsidies by 2017 (Verme and El-Massnaoui 2015).

Despite these institutional and organizational reforms, private companies have had limited involvement in manufacturing parts and components and in providing services for the emerging renewable energy sector. Job creation has also lagged behind.

3.2. SUPPLY SIDE MEASURES

From the beginning of this move toward a green economy, the Moroccan government has made it clear that its goal is to harness industrial development opportunities from its large investments in renewables. This section first reviews the measures taken to achieve that goal, provides a snapshot of existing capabilities of manufacturing and services in the private sector, and critically discusses whether these measures contribute to achieving the stated objectives of building local knowledge and capabilities.

POLICIES AND PROGRAMMES

Morocco's industrial development strategy, *le Pacte National pour l'Emergence Industrielle* 2009–2015 (le Pacte), has been a successful instrument to orient the development of strategic sectors for Morocco, such as agriculture, automotive and aeronautics, electronics, textiles and leather and offshoring services. The strategy consists of measures that are both directly targeted at specific sectors, as well as cross-sectoral, specifically improving the competitiveness of small and medium enterprises, improving the business environment, education and training and developing industrial parks for new sectors, including *P2I–Plateformes Industrielles Integrées. Le Pacte*, and its 2014 revision *Plan d'Accélération Industrielle du Maroc,*[24] has proven to be particularly effective for the automotive and aeronautics sectors, not only

24 An important component of the *Plan d'Accélération Industrielle* is its emphasis on local content creation through support programmes for the small and medium enterprises, and the formation of ecosystems in strategic sectors. In 2015 a dedicated industrial development fund (*Fonds de Développement Industriel*) has been created aimed at doubling the local value added in the automotive sector, for example (L'Usine Nouvelle 2014).

in terms of higher levels of investment but also in terms of moving up the technology ladder in local manufacturing and exports (Achy 2015; Ait Ali and Msadfa 2016). Along with *le Pacte*, the Moroccan Innovation Initiative was launched in 2009, aiming to improve Morocco's global competitiveness. One objective of this initiative is to set industrial clusters and 'Cities of Innovation' by 2016 to facilitate the commercialisation of research and technology transfer in various sectors.

The energy sector, however, was not initially targeted by the larger industrial development strategy. As industrial development was seen to be a secondary objective to the energy security goal, it was the Ministry of Energy, Mining, Water and the Environment (MEMEE) and in particular the new organization MASEN–instead of the Ministry of Industry, Trade and New Technologies (MCINET)–that were tasked to develop a concept for an emerging renewable energy sector. Nevertheless, the cross-sectoral incentives included in *le Pacte*, and later in *le Plan d'Accélération Industrielle*, were also applied to investments in the renewable energy sector. In addition, the MCINET notified potential investors and local companies interested in investing in the renewable energy sector about a bundle of standard and specific support measures. The bundle includes support for training and hiring through the *Agence Nationale de Promotion de l'Emploi et des Compétences*; benefits stemming from free zone status; corporate tax incentives and free repatriation of profits and capital for non-residents. It also offers investment grants from the *Fonds de Développement Energétique* for new investments in manufacturing parts and components for renewable energy and energy-efficiency technologies, up to 10 per cent of the acquisition cost of new capital goods, but not more than MAD (Moroccan dirham) 20 million. Other incentives for large-scale investments, larger than MAD 200 million, are also offered with respect to access to land, infrastructure, training, as well as exemption from value added tax and customs duties for three years (Invest in Morocco 2013).

The upgrading needs of the small and medium enterprise sector are served by the *Agence Nationale pour la Promotion de la Petite et Moyenne Entreprise* (ANPME), which offers not only financial incentives but also individual consulting services through their programmes Moussanada and Imtiaz. Moussanada offers support programmes to accelerate the use of information technologies in the firms; to improve strategy, marketing and organization; and to improve business skills such as production processes, procurement, design and research and development. Imtiaz is a national investment competition for high-potential enterprises offering grants for up to 20 per cent of the total investment costs. The programme objective is to increase turnover, support export activities and job creation and to introduce new technologies or structural changes within the specific sector (ANPME 2013). ANPME also offers individual consulting and support assisting companies to elaborate a development strategy, a *Plan de Progrès*, customised to their individual needs and objectives.

While these different programmes have been recognised to be highly beneficial, further improvements would be necessary, for example improving standards, visibility, and processing time. Specifically, many companies are not aware of the services offered by ANPME. Others claim that the trade-off between the time invested to learn about these services and using them is too high, and that they could also benefit from further customised incentives and support to the needs of the renewable energy firms. Also, companies operating in the renewables sector express need of a clear roadmap for industrial upgrading, similar to the one applied in the automotive and aeronautics sector (Vidican et al. 2013).

MCINET has played an important role in channelling support for the emerging renewable energy sector. But that has been only marginal, relative to its role in the development of other sectors in Morocco. MASEN's role has been much more prominent not only by commissioning and developing new large scale projects, but also by elaborating a vision for the renewable energy sector, particularly solar. The *Office National de l' Électricité et de l'Eau Potable* has been responsible for wind energy. Both are concerned with value chain localisation and enhancement of domestic local knowledge capabilities. The perceived disconnect and limited coordination between these important stakeholders has been a source of concern for some companies active in this emerging sector (Vidican 2015).

EXISTING CAPABILITIES

Capabilities along the value chain of renewable energy technologies are relatively low in the Moroccan private sector, existing mainly in steel products, civil works, electrical works, electronic equipment and cable manufacturing. Technological capabilities required for knowledge-intensive goods and services, such as engineering, design and project development skills, especially for large power plants, are currently missing or very weak. Most companies active in the solar energy sector are involved in the distribution and installation of imported parts and components for solar technologies. The local value added from these operations is, therefore, low. Only a few companies operate as manufacturers, and even fewer are active in project development and engineering. As for start-ups, only a couple of companies have emerged in this sector.

As the technical characteristics of different solar energy technologies and their value creation potential vary, it is crucial for Moroccan companies and policymakers to choose carefully what niche and what technology they work with (Vidican et al. 2013: 49–51). While solar photovoltaic is likely to generate more jobs for installed kWh, concentrated solar power is more capital intensive but can address energy security issues more effectively. Decision-makers have emphasized concentrated power much more than photovoltaic in the national deployment strategy; however, local companies have knowledge capabilities primarily in the photovoltaic technology and its small-scale applications. The small market size for this technology prevents local small and medium enterprises from scaling up their activities. Maximising the benefits from the large investments in concentrated solar power will therefore require concerted effort to establish linkages between technology providers and local suppliers.

The industry association *Association des Industries Solaires et Eoliennes* has played an important role both in terms of lobbying for the interests of the small and medium enterprises as well as in linking to other relevant stakeholders, such as research and academia. But, the market for photovoltaics has been small, until recently, and only a few manufacturers are present in the sector, so their leverage on policymakers has remained limited.

The level of technical education in Morocco is among the highest in North Africa. However, renewable energy technologies represent a relatively new field of knowledge for the country's universities. Basic research on renewable energy technologies started in the 1980s. However, applied knowledge remains scattered due to the lack of funding and low interest in the field research and education programmes. Following the National Energy Strategy adopted in 2009, curricula for renewable energy education programmes have been integrated in most universities, and research platforms have been developed, triggered primarily by the newly created *Institut de Recherche en Energie Solaire et en Energies Nouvelles* (IRESEN). IRESEN is a research institute that was modeled on Fraunhofer Research Institutes in Europe and the National Renewable Energy Laboratory in the US, with the aim of bridging the gap between academia and the private sector and enhancing innovation and entrepreneurship in Morocco. To understand and boost capabilities in Morocco's small and medium enterprises, IRESEN first organized a series of calls for joint applied research proposals between partners in universities and local firms. One of the objectives of these calls was to identify high potential firms and local experts. Then IRESEN, supported by the largest globally competitive Moroccan company in the sector of phosphates, the *Office Cherifien des Phosphates*, created the innovation and education platform Green Energy Park. The Green Energy Park is the first platform in Africa to create synergies between different research institutions and contribute to building knowledge capabilities in both the academic and private sectors. The international partners for the Green Energy Park include Fraunhofer Center for Silicon Photovoltaics, the German Aerospace Center, PVcomB Helmholtz Zentrum Berlin and the Korean International Cooperation Agency (IRESEN 2017).

Such initiatives and the large investments in the sector also mobilised local universities to coordinate their activities and boost cooperation efforts nationally and internationally. The Moroccan Society of Renewable Energy Development and the *Mastère National en Energie Renouvelable et en Efficacité Energétique* are networking platforms that emerged along with the national strategy for renewable energy, not only bringing together academics and firms, but also finding ways to adjust the university curriculum to the needs of the private sector.

In a parallel effort, MASEN has been coordinating, in collaboration with German development cooperation agencies, the creation of a solar industrial cluster, *Cluster Solaire*. The concept was launched in 2014 to complement activities at the large concentrated power plants in Ouarzazate Solar Complex and to support the enhancement of small and medium enterprises' capabilities. The Climate Innovation Center in Morocco is also a supporter of this cluster project, thus creating further synergies between initiatives that were previously disconnected. Among the members of the cluster, which currently operates mostly as a coordinating platform, are industry associations and higher education institutions, as well as companies from relevant sectors such as energy, metallurgic and electro-mechanics. Its main objectives are to enlarge the market, increase local value added, develop local competencies, attract financing for innovative projects and develop an attractive regulatory framework (Cluster Solaire 2016).

Most of these initiatives have emerged bottom-up, without much coordination through strategic interventions. For instance, the Ministry of Higher Education, Scientific Research and Professional Formation has been virtually missing from strategic discussion about the development of this sector. However, without effective coordination and cooperation among all these initiatives, the impacts on the local economy are likely to remain limited

BUSINESS LINKAGES

Given that most investments in renewable energy in Morocco are in large-scale projects, developed and implemented by consortiums of technology-intensive lead firms, establishing linkages between technology providers and local small and medium enterprises is essential for enhancing domestic capabilities through knowledge transfer. Thus they should be a core element of green industrial policy. In their cooperation with the smaller enterprises, lead firms or transnational corporations define product and process standards along the supply chain, thus forcing their local partners and suppliers to upgrade their industrial performance (Altenburg 2005). The large production capability of transnational corporations, coupled with the flexibility and specialisation of small and medium enterprises, allows for successful technology transfer through spillover and trickle-down effects across the entire sector.

In Morocco, the experience with business linkages, at both institutional and firm levels, is limited to few companies in sectors such as automotive, aeronautics and transportation infrastructure. In the emerging solar sector, business linkages remain scarce. The local entity with the direct mandate of facilitating linkages between foreign companies and small and medium enterprises is the *Bourse Nationale de Sous-traitance et de Partenariat* (BNSTP). Yet, due to understaffing, financing gaps, and lack of a vision with respect to enhancing competitiveness in the private sector, BNSTP has remained ineffective and almost invisible to foreign investors and most local companies. This role has been indirectly played either by industry associations or regional investment offices.

Business partnerships or joint ventures, firm-level training programmes, technology licensing and supplier development programmes are among the most successful mechanisms to transfer technology and know-how between enterprises. Local content requirements have also been used to support the transfer of knowledge. In the Moroccan renewable energy sector, joint ventures are very limited. In the wind sector Nareva Holding, a renewables company owned by Morocco's *Société Nationale d'Investissement*, established a joint venture with the French energy group GDF Suez to be responsible for building and operating a wind farm. A more recent development is the UAE's clean energy company Masdar's plan to set up a 70 per cent-owned joint venture to develop three solar power plants in Morocco (Yaneva 2015). The relatively small market for renewable energy technologies in Morocco is viewed as the most limiting factor for developing business partnerships.

Inter-company training can also be an effective mechanism for knowledge transfer. Several companies in the solar energy sector indicate that they did benefit from such training activities (Vidican et al. 2013). Training can materialize by sending employees to the 'mother' company abroad for hands-on education in manufacturing facilities, by the creation of 'learning rooms' in the manufacturing facility in Morocco together with local universities and by operational training not only about the particular installation but also about the technology.

Successful supplier development experiences suggest that such programmes work best when driven by lead firms rather than imposed by decision-makers. Yet, although lead firms should select their own partners and design adequate supplier programmes, national agencies can act as facilitators and support with various services such as upgrading programmes, education and training. The French transnational company, Alstom, has an elaborate supplier development programme in Morocco that is considered to be the most effective and can be used as a learning platform for others as Alstom is seeking to expand its investments in the renewable energy sector. Alstom's experience underlines how important it is for local companies to have a certain level of basic standards and processes in place to be considered as potential suppliers (Vidican et al. 2013: 133–134). Government-sponsored programmes channelled through ANPME or other organizations would, therefore, be necessary.

Due to restrictions imposed by multilateral financial institutions,[25] local content requirements for renewable energy investments are set on a voluntary basis. In the Noor I concentrated solar

25 Morocco has not signed the World Trade Organization plurilateral Agreement on Government Procurement from 1994/1996 and thus mandatory local content requirements are not generally prohibited (Vidican et al. 2013: 136).

power project at the Ouarzazate Complex, a 30 per cent local content requirement was set, achieved mainly in the construction phase. The expectation is that in the next phases, Noor II and Noor III, a 35 per cent share of the goods and services will be sourced locally (Oxford Business Group 2016). But, as the local contribution in these large projects comes mostly from civil works and steel structures, opportunities for acquiring technological capabilities remain limited. For local content requirements to be effective, regardless of whether they are set on a voluntary or mandatory basis, a sizable and stable market is needed and a gradual increase over time is also important, in consultation with relevant stakeholders. The effectiveness of the local content requirements also closely depends on other measures aimed at reducing the technological gap between lead firms and local small and medium enterprises, such as industrial upgrading programmes. A systemic approach to industrial policy, and green industrial policy in particular, is therefore essential.

3.3. INTEGRATED STRATEGY FOR INDUSTRIAL DEVELOPMENT

All these institutional structures and interrelating initiatives demonstrate the need for a comprehensive national strategy for the development of the renewable energy sector in Morocco. Without a strategy that targets both the creation of a sizable market for renewables and the development of a local industry–objectives of green industrial policy–stakeholders do not receive the necessary signals to invest and engage in the emerging sector (Vidican et al. 2013). Since 2009, when Morocco's National Energy Strategy was issued, important steps towards consolidating and aligning different initiatives have been taken. Yet, further steps are needed, as a concrete integrated strategy for industrial development in the realm of renewable energy is still lacking. *Le Pacte* could serve as an example in this regard.

The development of the renewable energy sector requires the intervention of multiple government agencies: MEMEE, MCINET, ANPME; levels of governance: national, regional, local; and various non-governmental organizations: education, research, civil society, private sector. This reality of green industrial policy calls for coordinating industrial development objectives through a multi-stakeholder governance process and ensuring a certain level of development directionality (Mazzucato 2014; Altenburg and Lütkenhorst 2015).

The development focus is important for Morocco to succeed in using renewable energy as a trigger for industrial development. Currently the industrial development part of the green industrial policy is the concern of various stakeholders with mandates in the renewable energy sector such as MASEN and IRESEN. The MCINET has played only an overarching role, not actively engaged with the stakeholders of this emerging sector. Yet, a unifying vision and a long-term perspective are necessary and they should be capable of bringing together these initiatives and orienting them towards a common goal. The role of MCINET in this process, with a national mandate from the Royal Court is critical. Altenburg and Lütkenhorst (2015:162) call this vision a 'national project of industrial transformation'.

Such a strategy would need to select renewable energy technologies that can deliver a higher value added for the local economy and a higher number of jobs, to attract investment and support the establishment of partnerships and joint ventures with local firms and to orient and adjust the education and research sector towards the needs of the new sector. Last but not least, green industrial policy should prepare local small and medium enterprises to engage in the value chain of renewable energy technologies, aiming to strengthen their capabilities through industrial upgrading programmes, setting up a national system of quality management and other targeted areas of intervention. As the Moroccan market is small compared to other countries, local companies should have the opportunity to gain sufficient experience at home to then be able to seek business opportunities abroad and thus positioning Morocco as a regional market leader.

Weak coordination of green industrial policy measures is a reality in Morocco, but it can be addressed. Various new agencies have been created to enable the attainment of the renewable energy targets, agencies that start collaborating with established agencies previously engaged with other industrial development goals. Bringing together and agreeing on a new vision, new objectives, and new ways of thinking about how to integrate traditional industrial and energy policy tools into a transformational agenda is not an easy task. Nevertheless, proactively seeking to streamline and harmonise these initiatives and to coordinate across stakeholders can contribute to convergence towards a national vision. Vidican et al. (2013) argue that such an integration and coordination effort could be steered by a new organization–specifically the Moroccan Solar Energy Council–that would bring together key stakeholders. Further reflections on which actors should take the lead in implementing such actions is necessary, in light of existing governance processes in Morocco.

Other aspects to consider are the integration of learning mechanisms in policy-making and strengthening of implementation capacity of the state bureaucracy. As OECD (2013:93f) argues, this requires a clear framework for policy evaluation and learning, so that incentive schemes and policy measures can be regularly monitored, evaluated and adjusted. As Rodrik (2009:22) also mentions "conditionality, sunset clauses, built-in programme reviews, monitoring, benchmarking, and periodic evaluation are desirable features of all incentive programmes". But, the implementation capacity of state bureaucracy can be, and often is, limited. Therefore, investing in improving the administrative capacity of the central state bureaucracy is also important.

4. CONSIDERATIONS FOR CAPITALISING ON EARLY STEPS

Following investments in renewable energy, the potential of creating a new competitive industry in Morocco is significant. These early steps of linking energy and industrial policy have opened up opportunities for synergies between different initiatives for expanding the market for renewable energy and developing capabilities in the private sector. In effect, even if not labelled as such by the national authorities, green industrial policy has been enabled in Morocco. Incentives for market creation made the creation of a market for renewable energy technologies possible and attracted much needed investment. Training programmes made it possible for skilled and unskilled workers to participate in the first projects. Education and research programmes contributed to increasing awareness of this new sector and of future prospects. Lastly, various support programmes for the private sector triggered interest in exploring investment opportunities in renewable energy.

To scale-up these initiatives and their outcomes, it is necessary to embed them in a systemic approach. A large market offers incentives for private investors to enter the market, as experienced in the wind energy sector in Morocco. Thus, eliminating regulatory barriers for low and medium-voltage projects is critical in this regard. Opening up this market segment will diversify the technology focus beyond concentrated solar power. That should bring small and medium enterprises into the supply chain for renewable energy technologies by manufacturing parts and components and providing associated services, in turn contributing to learning and improvement in competitiveness. A larger market also opens up opportunities for a wider targeting of technologies with diverse degrees of local value added potential.

Moreover, targeted support measures for upgrading capabilities in the small and medium enterprise sector can assist not only local companies but also encourage lead firms to create linkages with local companies and thus to localise knowledge. So far, support measures have not been well targeted to the specific needs of companies in this sector; therefore they have not been very effective. As consortia of technology-intensive lead firms have developed the first large projects, critical steps could be made in developing a base of local suppliers of certain parts and components along the value chain. Gaining a better understanding of local manufacturing and service provision capabilities is essential. The earlier experience with attracting investments and developing a competitive automotive and aeronautics sector in Morocco—through comprehensive supplier development programmes and synergetic initiatives in training, education, and research—could offer relevant lessons to the development of a renewable energy sector. To this end, a more detailed understanding of the factors that contributed to positive outcomes in these other sectors is necessary, followed by a reflection on lessons that could be transferred to the renewable energy sector.

Ultimately, an integrated national strategy is critical, as is a long-term vision for developing this sector that stresses learning, not only from earlier steps but also from Morocco's experience with the development of other sectors. Its favourable location and stable political environment, as well as its consistent efforts to develop their renewable energy potential, could help position Morocco as a regional player in this sector. The success of such an effort is conditional on correcting earlier shortcomings, especially with regards to enabling further structural reforms. Areas for attention include the labour market and business climate, increasing public dialogue, fostering business and civic engagement and strengthening alignment across administrative functions.

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CHAPTER 11

GERMANY: THE ENERGY TRANSITION AS A GREEN INDUSTRIAL DEVELOPMENT AGENDA

Anna Pegels

1. THE ENVIRONMENT AS A DRIVER OF GERMAN INDUSTRY

Generating about 20 per cent of Germany's gross domestic product (GDP) in 2014, manufacturing value added plays a major role in the German economy (UNIDO 2016). Among EU countries, only the Czech Republic has a slightly higher share of manufacturing value added in GDP. The EU average stands at 14 per cent.

Environmental goods and services have rapidly risen in importance for the German economy. According to *Statistisches Bundesamt* (2015), they provided about 260,000 jobs and generated a turnover of about EUR 66 billion in 2013. About 77 per cent of the jobs were located in manufacturing, producing about EUR 51 billion in turnover. The Federal Ministry for the Environment, using a broader definition, even calculates a market volume for environmental technologies and resource efficiency of EUR 344 billion in 2013, which is 13 per cent of German GDP (BMUB 2014). It estimates the market will grow by a yearly average of 6.6 per cent to EUR 740 billion in 2025, at that point accounting for more than 20 per cent of GDP.

This development is supported strongly by German policy making, most notably by the *Energiewende*, or energy transition. With competitiveness as an explicitly stated aim, the *Energiewende* cannot be regarded as only an environmental policy, but needs to be seen as a green industrial policy. It certainly is one of the most ambitious energy transition ventures globally. It aims to steer the German energy sector towards sustainability by meeting a combination of quantitative targets for greenhouse gas reduction, renewable energy, and energy efficiency, which are discussed in more detail in section 2.

The environmental targets form an integral part of the *Energiewende*, but a green industrial policy strives not only for environmental objectives, but also for a complex set of economic and social objectives. Typically, the latter include technological innovation, competitiveness, value added, and employment creation. These aims and the policy measures of the *Energiewende* are discussed in section 3.

Other countries, among them numerous developing and emerging countries, have implemented or are planning similar sustainable energy policies, such as renewable energy feed-in tariffs, although with less ambitious technology deployment objectives. Germany, and the successes and setbacks of its *Energiewende*, are thus under close international scrutiny. While the jury is still out on the success or failure of the *Energiewende*, the discourse in recent years has been vehement. Section 4 sets out to contribute some objectivity to that discourse by analysing data on patents, trade, employment, and value added as indicators for the success of the *Energiewende* as Germany's green industrial policy flagship. From this analysis, and a subsequent discussion of the achievements and remaining challenges of the *Energiewende*, section 5 aims to derive lessons for other countries' energy transitions; and, by presenting other countries' lessons, for Germany.

2. AIMS AND POLICY MEASURES OF THE ENERGY TRANSITION

The stated policy aims of the *Energiewende* are (BMWi 2015a):

- Greenhouse gas emission reductions
- A complete phase-out of nuclear power by 2022[26]
- Competitiveness
- Security of energy supply.

Jungjohann (2016) sees this array of aims as building blocks for the success of the *Energiewende*. Combining the various aims enables the forging of coalitions that are vital for the implementation of a national project of such order and socio-technological complexity as the *Energiewende*, and the grounding of the *Energiewende* in society through the facilitation of energy cooperatives may have been one of the building blocks of much needed societal support (Schmitz 2016;

26 The decision to phase out nuclear power in Germany goes back to a longstanding societal discourse, which gained impetus after the nuclear catastrophe in Chernobyl in 1986. After the catastrophe in Fukushima in 2011, the German government decided to phase out all nuclear power generation by 2022.

Jungjohann 2016). Nonetheless, several windows of opportunity were necessary to overcome resistance from incumbent industries, among them the German reunification, the discussions around an environmental tax reform, and the nuclear incident in Fukushima (Jungjohann 2016).

The policy aims of the *Energiewende* were separated into the two strategic aims of increasing the share of renewable energies and increasing energy efficiency, with both aims tracked in the electricity, heat and transport sectors. The German government has set a number of quantitative mid- and long-term targets for these sectors (Table 11.1).

Table 11.1: Quantitative targets and status quo 2014 of the *Energiewende*

	2014	2020	2030	2040	2050
Greenhouse gas emissions					
Greenhouse gas emissions (compared to 1990)	-27%	at least -40%	at least -55%	at least -70%	at least -80% bis -95%
Renewable energy					
Share of gross final energy consumption	13.5%	18%	30%	45%	60%
Share of gross electricity consumption	27.4%	at least 35%	at least 50% Renewable Energy Sources Act 2025: 40–45%	at least 65% Renewable Energy Sources Act 2025: 55–60%	at least 80%
Share of heat consumption	12%	14%			
Share in transport sector	5.6%				
Efficiency and consumption					
Primary energy consumption (compared with 2008)	-8.7%	-20%	→	→	-50%
Final energy productivity (2008–2050)	1.6%/year (2008–2014)	2.1%/year (2008–2050)			
Gross electricity consumption (compred with 2008)	-4.6%	-10%	→	→	-25%
Primary energy consumption in buildings (compared with 2008)	-14.8%		→	→	-80%
Heat consumption in buildings (compred with 2008)	-12.4%	-20%			
Final energy consumption (compared with 2005)	1.7%	-10%	→	→	-40%

Source: BMWi (2015d: 4).

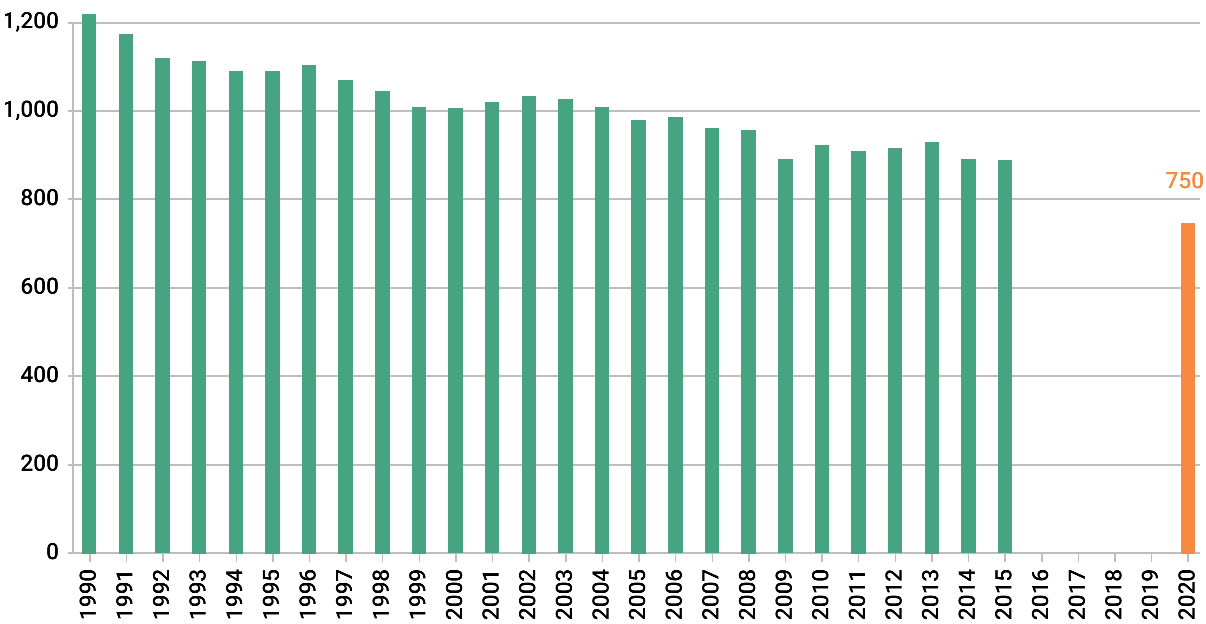
To achieve the aims of the *Energiewende*, the German government introduced a number of policy measures. The most significant and most disputed measure is the system of feed-in tariffs for renewable energy, established in 2000 in the Renewable Energy Sources Act, *Erneuerbare-Energien-Gesetz*. These preferential tariffs complement various loan programmes for renewable energy, research and development support through the Federal Energy Research Programme and sector-specific innovation and cluster support programmes (Lütkenhorst and Pegels 2014).

3. HOW TO MEASURE PROGRESS TOWARDS ACHIEVING THE *ENERGIEWENDE* AIMS?

Measuring progress on the targets set out in Table 11.1 is relatively easy, and the quantitative indicators for renewable energy deployment, energy efficiency, and greenhouse gas emission reductions are helpful to assess the progress of the technological dimension of the *Energiewende*.

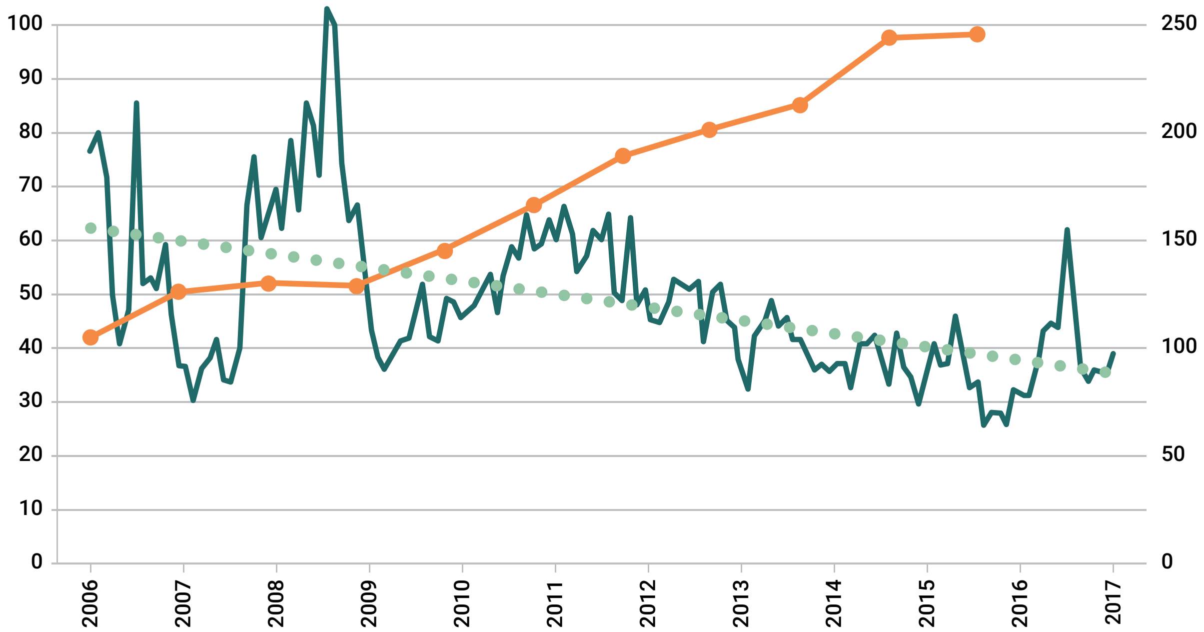
Progress on the targets has so far been mixed. Renewable energy shares have been rising steadily, reaching more than 30 per cent of gross electricity consumption in 2015 (BMWi 2015a). In this regard, the *Energiewende* is well on track. The other targets have seen less progress, though. Greenhouse gas emissions declined rapidly in the first years after the German reunification in 1989, but this decline was largely due to the dismantling of Eastern German heavy industry. Since then emission reductions have slowed, and since 2008 in particular no substantive emissions reductions occurred. As shown in Figure 11.1, efforts need to be reinforced to meet the target of reducing emissions to a maximum of 750 Mt CO_2e by 2020, in accordance with a 40 per cent reduction from 1990 emissions levels. One reason for the slow progress in emissions reductions is the trading of electricity in the spot market, combined with an electricity oversupply from unexpected levels of renewable electricity generation. This oversupply led to a decrease in electricity spot-market prices (Figure 11.2). The depressed price crowded the more expensive but cleaner fossil fuel options out of the market first. So natural gas generation, for example, slows first, while cheaper sources, such as lignite, remain– and lignite is the most polluting electricity source in Germany. In sum, growth in renewable energy sources triggers a market response that results in the increased use of the most polluting fossil fuel source, lignite, because it is the cheapest. So, emission levels remain stagnant, despite rising shares of renewables and improvements in energy efficiency.

Figure 11.1: German greenhouse gas emissions 1990–2015, target 2020 (in million tonnes CO_2 equivalents)



Source: Umweltbundesamt (2017).
Note: Figure includes emissions from land use, land-use change and forestry (LULUCF).

Figure 11.2: European Energy Exchange electricity spot-market prices in Germany (green, trend as dotted line, EUR / MWh, left axis) against renewable electricity generation (orange, TWh, right axis)



Source: based on BMWi (2017a), BMWi (2017b).

Improvements in energy efficiency have not been sufficient either. Instead of the targeted 2.1 per cent per year, final energy productivity improved only by an annual 1.6 per cent between 2008 and 2014. Final energy consumption in transport saw a small increase of 1.7 per cent between 2005 and 2014.

While the targets are useful to measure the technological and environmental progress of the *Energiewende*, they do not capture the industrial policy aspects of *Energiewende* aims in their entirety. Measuring the success of the *Energiewende* as an industrial policy agenda thus requires additional consideration. Two questions need to be answered: First, has the *Energiewende* enhanced the competitive position of green industries, and second, have effects on the performance of other industries, for example through electricity price changes, been positive or negative?

To answer these questions, the subsequent sections will use various types of data. First, to indicate progress on typical industrial policy aims in green industries, they will use:

- Trade data indicating competitiveness of green industries on international markets
- Patent data and research expenditure indicating innovativeness in green technologies
- Data on value added by green industries
- Employment data to assess the job creation potential of green industries.

Second, they will draw from aggregate indices and survey data such as the Global Cleantech Innovation Index of the Cleantech Group, the Global Competitiveness Index of the World Economic Forum, and the *Energiewende* Barometer of the German Chamber of Industry and Commerce.

The technical details of data use and sources are discussed in the respective subsequent sections. Two caveats are in order: First, since 'green energy' is not a category usually captured by conventional statistical classification, providing a harmonised picture across all indicators is notoriously difficult. Depending on definitions, data availability and database groupings, this assessment will concentrate on a selection of typical green energy technologies, such as renewable energy and energy storage technologies. Since most detailed data are available for renewable energy technologies, these will be assessed in subsequent sections, but other technologies are brought into the analysis where possible to provide a broader picture. Second, effects on the competitiveness of industries other than the selected ones, for example through electricity price changes, will be discussed in a more qualitative and descriptive way, since a comprehensive and detailed discussion of effects on all German industries would be beyond the scope of this chapter.

4. THE *ENERGIEWENDE* AS INDUSTRIAL DEVELOPMENT AGENDA

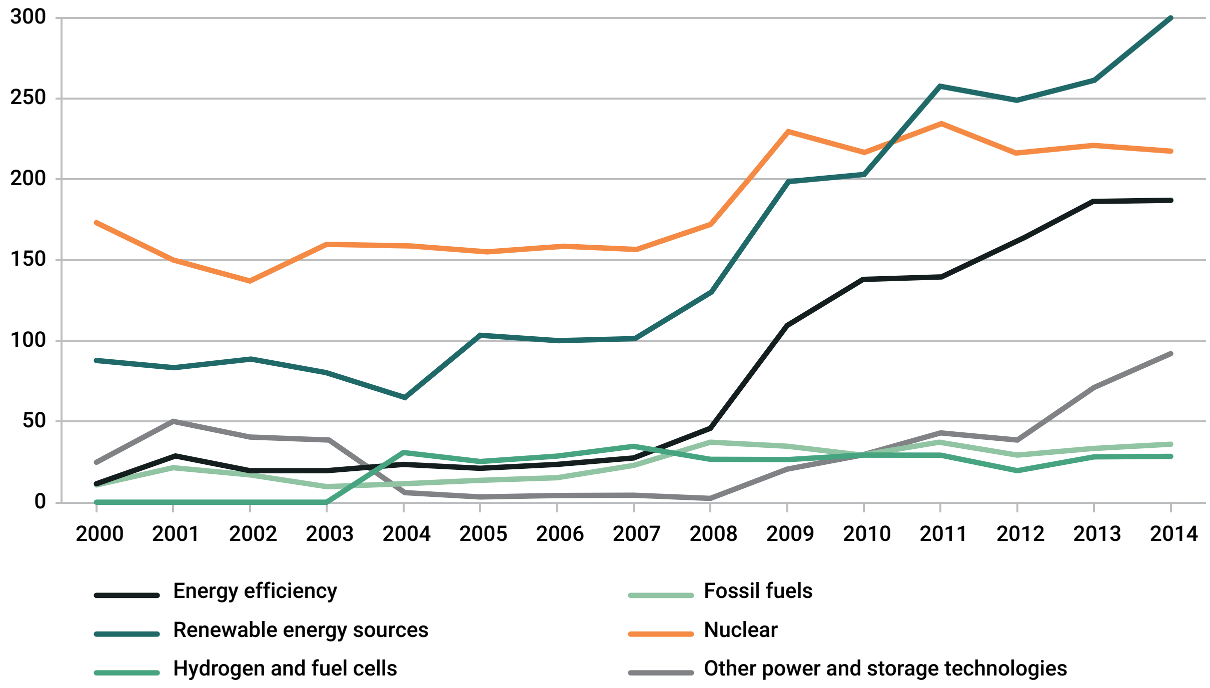
4.1. INNOVATION

The World Wildlife Fund and Cleantech Group developed and biannually calculate the Global Cleantech Innovation Index, which gives an aggregated overview of countries' innovation potential in clean technologies. Among 40 countries, it seeks to identify those with "the greatest potential to produce entrepreneurial cleantech start-up companies that will commercialise clean technology innovations over the next 10 years" (Sworder et al. 2017:3). It uses 15 indicators related to the creation, commercialisation and growth of clean technology start-ups. According to this index, Germany ranked 8th in 2017, after Denmark, Finland, Sweden, Canada, the US, Israel, and the UK. Germany's score in general innovation drivers is relatively low, with a rank of 19. The 2014 report attributed this weakness to a lack of "positive attitude towards entrepreneurship or level of early stage entrepreneurial activity" (Parad et al. 2014: 41). The 2017 report confirms the weakness in early-stage entrepreneurship, ranking the country second-to-last in this indicator, just ahead of Italy. In contrast, Germany scores first in environmental patents, and is strong in clean technology exports and renewable energy jobs. Despite the low level of early-stage entrepreneurship, its strong industry and established manufacturing sectors allow it to efficiently convert innovation inputs into outputs.

To add detail to this general picture, this section will use disaggregated data on German research expenditure as the input indicator and patents as the output indicator of innovativeness in clean technologies. Data is sourced from the data warehouse of OECD, OECD.stat, which includes data and metadata for OECD countries and selected non-member economies (OECD 2015). These databases provide pre-selected technology groupings such as renewable energies or hydrogen and fuel cells, which will be used in the subsequent analysis. Energy efficiency technologies will not be included in the analysis since drawing the boundaries for this technology group is particularly challenging (Ekins et al. 2015:44). Any data presented would thus be open to criticism, and comparability across databases would be very limited.

Data on research and development expenditure in energy technologies refer to public expenditures (Figure 11.3). As can be seen, total German expenditure for research and development of renewable energies has been following a clear upward trend in recent years. Within OECD countries, Germany's 2014 expenditure for renewable energies research ranked at 3rd, for nuclear energy at 3rd, for hydrogen and fuel cells at 3rd, and for energy storage at 2nd, compared to a 6th rank in fossil fuel research (OECD 2015). Since 2010, renewable energies have been the most highly funded research area. Nuclear energy research funding has stagnated at a relatively high level, while funding for research on storage technologies has grown from a lower level. Hydrogen and fuel cells and fossil fuels have received comparatively little public research funding.

Figure 11.3: Research, development and deployment budget energy technologies, Germany (million EUR)

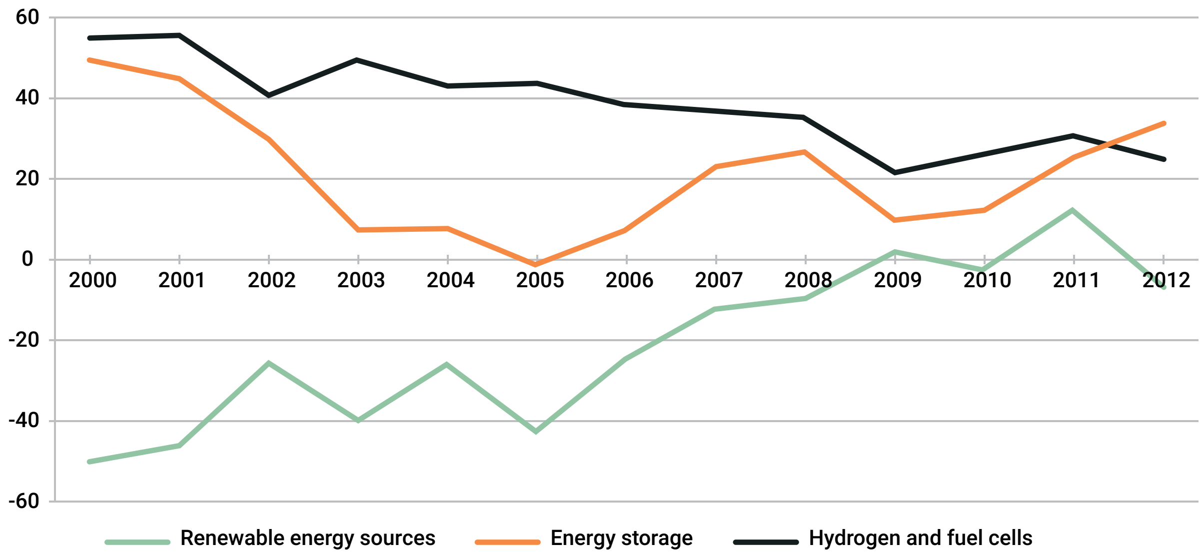


Source: OECD (2015).

While research budgets are useful as input indicators, they do not provide information on the success of research activities. This success is often measured by patent data, since patents can be considered as an output of research activities.

One possible measure of the national innovative strength in specific technologies is the relative patent share, which compares a country's world patent share in the specific technology with its share in all other technology patents. Relative patent share is normalized to assume values between -100 and +100. A positive value indicates that the world share of the patent for a certain technology is larger than that of all patents of the same country, and values higher than 20/lower than -20 indicate an innovative strength/weakness in the assessed technology (Umweltbundesamt 2014).

Figure 11.4: Relative patent shares in relevant energy technologies, Germany



Source: OECD (2015).

While the German relative patent share values for renewable energy generation have been declining, they are consistently positive at values higher than 20 (Figure 11.4). Germany thus has an innovative strength in these technologies, likely mirroring the supportive policy environment of the *Energiewende*. The decline is likely attributable to increasing competition from non-OECD countries, in particular China (Ekins et al. 2015). The growth of the Chinese domestic market, the location of international renewable energy firms in China and the increasing importance of Chinese domestic firms have contributed to increased innovative activity.

Values for hydrogen and fuel cell technologies are positive as well, but below 20 in most years. The picture for energy storage is less positive: while relative patent share values have been increasing, they exceeded values of -20 only from 2007, and have been oscillating around zero since. This shows an innovation weakness in energy storage technologies. Competition from Japan and China is particularly strong: between 2004 and 2013, 39 per cent of patent applicants were Japanese, 28 per cent Chinese, and only 7 per cent German (UK Intellectual Property Office 2014).

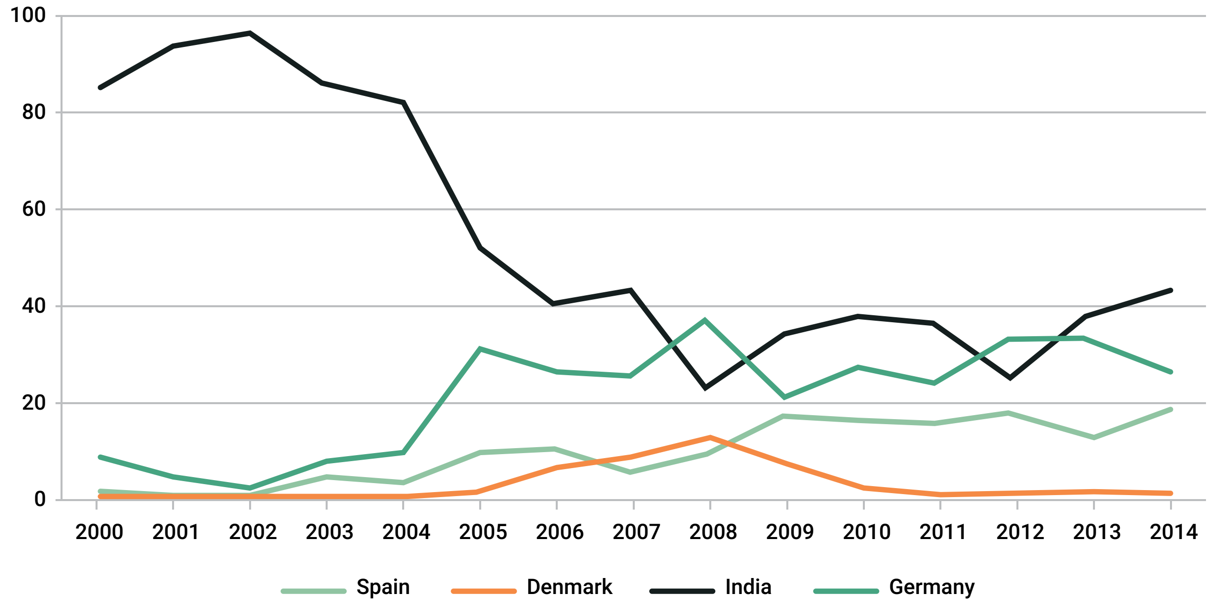
4.2. COMPETITIVENESS

WORLD MARKET SHARES IN CLEAN ENERGY TECHNOLOGIES

Many indicators are available to measure the international competitiveness of industries and most involve trade data. One of the most intuitive indicators is the world market share, which illustrates the share each country has in world exports for a given product. This section concentrates on Germany's trade performance in selected renewable energy technologies compared to its most relevant competitors in the same technologies.

Germany's world market share in wind energy converters has been fluctuating around 30 per cent for the past ten years (Figure 11.5). The low world market share before 2005 is explained by the fact that in those years Germany represented a lead market for wind energy—accounting for 45 per cent of wind energy converter installations worldwide in 2002, but falling to 7 per cent in 2005. The pioneering feed-in tariff introduction had created such a strong domestic market pull that early export efforts were effectively stifled (Lütkenhorst and Pegels 2014). Since 2008 Germany has been competing for world market leadership with Denmark, which has been a dominant player since the early stages of the technology.

Figure 11.5: World market shares wind energy converters



Source: WITS database, World Bank (2015).

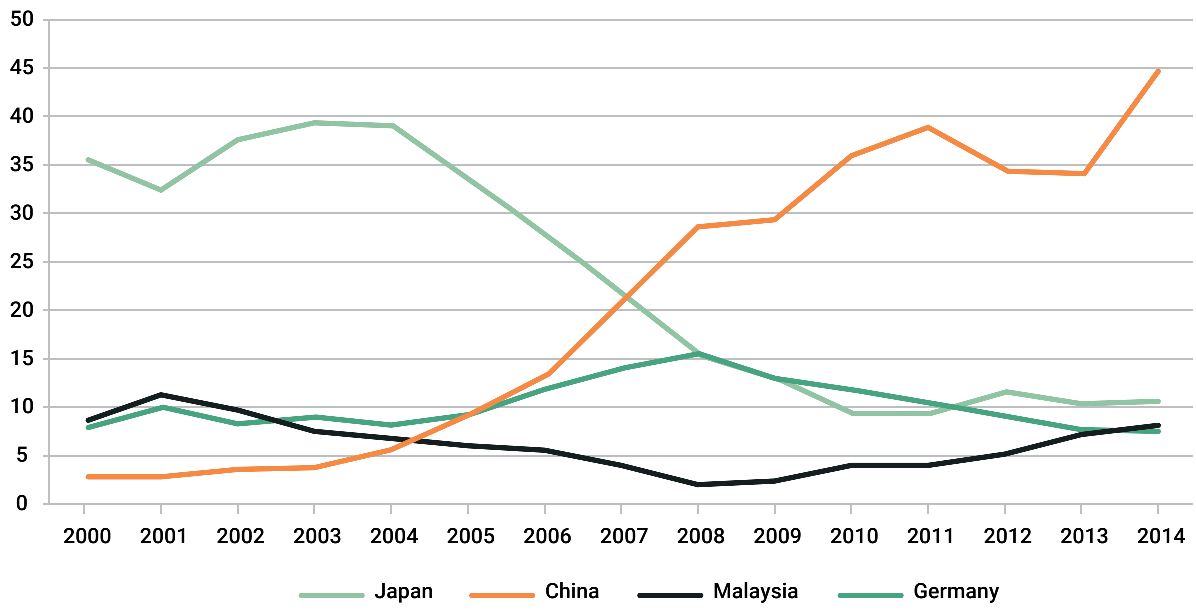
Beyond the aggregate data presented in the chart, industry analysts underline the particularly strong competitive position of German companies when it comes to offshore turbines and offshore wind parks in general, as well as large-scale onshore turbines above 5 MW capacity (Lema et al. 2014; Lütkenhorst and Pegels 2014). Most recently the German company Siemens, which is leading in offshore wind technology, bought 59 per cent of the Spanish company Gamesa, which has a strong position in emerging country markets (Spiegel 2016). With about EUR 9.3 billion in annual sales volume, the merger has created one of the world's biggest multinational wind companies.

A particular driver of competitive strength originates from a classic technology cluster in the four Northern states of Lower Saxony, Schleswig-Holstein, Bremen and Hamburg. This North Western Wind Power Cluster has grown into a densely interconnected web of more than 300 partners including globally leading turbine manufacturers, specialised component suppliers, wind park operators, local governments and cutting-edge research institutions. The cluster boasts some of the industry's major innovations, such as the development of the 5 MW offshore turbines and the offshore test site Alpha Ventus.

At the same time, the wind cluster also owes some of its success to the long-standing track record of Germany's engineering, machinery and power sectors in general. Without the foundation of highly advanced manufacturing capabilities and skills across a whole range of industries, the German wind energy sector would not have been able to achieve its current global position. Arguably, the North Western cluster represents an internationally unique level of sophistication and comprehensiveness, with business players along the entire value chain exhibiting a high intensity of interactions based on shared ambitions and quality standards. The cluster represents a genuine public-private partnership and is co-funded by state resources and business membership fees.

In the field of solar photovoltaic cells, in contrast, Germany was not able to gain a strong market position. While the country's global market share increased from about 7 per cent in 2000 to 15 per cent in 2008, it has fallen back to 2000 levels since (Figure 11.6). Background data show that German exports of solar photovoltaic cells were almost cut in half between 2010 at US$ 8.1 million and 2012 at US$ 4.5 million (Lütkenhorst and Pegels 2014). Several German photovoltaic companies went bankrupt during this time, such as Solon, Q-Cells and Odersun (Parad et al. 2014). At the same time, the rapid increase of the Chinese world market share is notable. Remaining below 5 per cent until 2004, it quickly rose to 45 per cent in 2014, making China the clear world market leader in the manufacture and export of photovoltaic cells.

Figure 11.6: World market shares solar photovoltaic cells



Source: WITS database, World Bank (2015).

Beyond the trends on photovoltaic cell manufacturing, the strong competitive position of German photovoltaic system component manufacturers and equipment suppliers must be emphasized. Data for 2011 show that the share held by German firms in the global market for specialised photovoltaic equipment was as high as 50 per cent, and the market share of photovoltaic inverters that transform the direct cell current into alternating grid current stood at 35 per cent (Germany Trade & Invest 2013). With a share of approximately 25 per cent, the German company SMA Solar is the world market leader for inverters. However, the company has recently been suffering from overcapacity and had to announce significant job cuts in the first quarter of 2013 (Lütkenhorst and Pegels 2014). In total, employment in the German photovoltaic industry nearly halved in 2013 and 43,900 people lost their jobs (Lehr et al. 2015).

In sum, Germany was successful in creating a competitive wind energy industry that can now reap economies of scale, while the picture is less impressive for the solar photovoltaic industry. Industrial policy investments in photovoltaic cell manufacturing did not bear fruit, which is not very surprising, since cell manufacturing is not overly sophisticated and cells and modules can easily be transported, making proximity to markets a less important factor. A large part of cell manufacturing activity thus relocated to China. However, while some firms went bankrupt, other parts of the German photovoltaic industry concentrated on more sophisticated activities upstream as cleanroom production facilities for manufacturing cells, for example, and downstream as system components such as inverters, mounting structures, and cabling. What we observe in the photovoltaic industry is a fairly typical transition: when cell manufacturing was still a cutting edge technology, Germany was a leading producer. Low cost assembly in China crowded German producers out when the technology matured, but German industry was able to build competitive advantages in specialised high-value niches of that industry. German industrial policy could have been more successful had it supported this transition earlier by focusing on technologically sophisticated steps in the photovoltaic value chain.

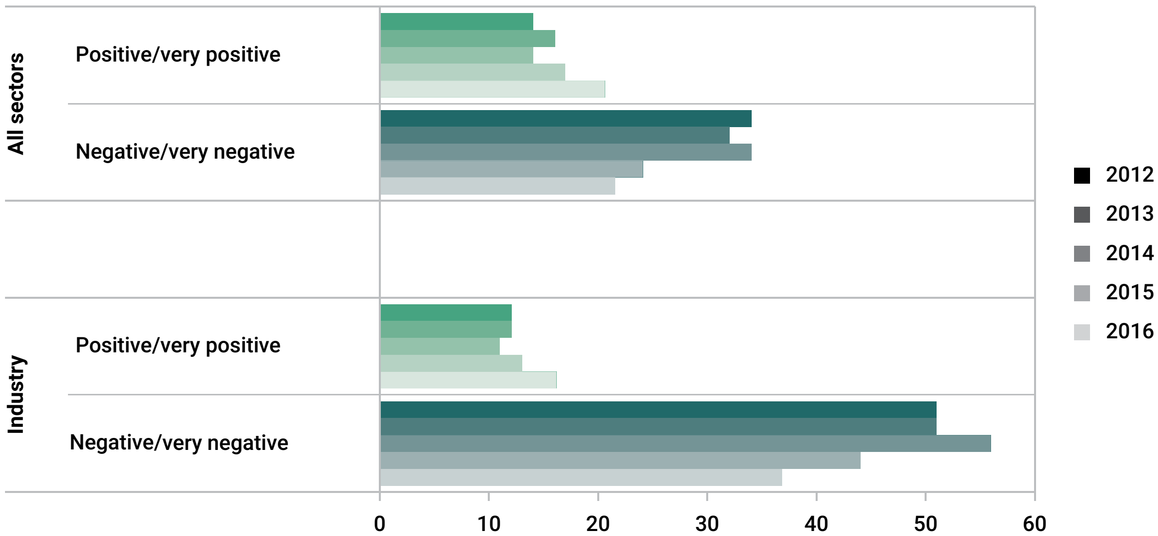
PERCEIVED IMPACTS ON COMPETITIVENESS IN OTHER SECTORS

When assessing the effects of the *Energiewende* on competitiveness, implications for new green industries are a central factor. However, indirect consequences for established industries need to be considered as well to obtain a more holistic view of net effects. These consequences are notoriously difficult to measure, since establishing causality can be challenging. To provide a rough picture of possible effects, aggregate data from the World Economic Forum's Global Competitiveness Index and the results of surveys conducted by the German Chamber of Industry and Commerce, *Deutsche Industrie-und Handelskammer* (DIHK) help illuminate the effects of the *Energiewende* on German industry.

On an aggregate level, the World Economic Forum's Global Competitiveness Index does not confirm a clear upward or downward trend for German competitiveness over the past years. Out of 140 countries, Germany ranked 6th in the 2012–13 Report, then 4th, then 5th, and 4th again in the most recent Report of 2015–16 (World Economic Forum 2015). Barriers to German competitiveness are mostly attributed to the complexity of tax regulations and high tax rates or to inefficient government bureaucracy and labour market rigidities, but not to energy price increases.

Focusing on the *Energiewende*, the DIHK presents the results of annual company and energy expert surveys in its publication '*Energiewende-Barometer*'. The first surveys were conducted in 2012, the most recent ones in 2017. In contrast to the results of the Global Competitiveness Index, the overall perception of *Energiewende* effects on competitiveness seems to be slightly negative, with a clearly negative perception in the industrial sector (Figure 11.7). Between 2012 and 2014, about half of the companies in this sector replied that the *Energiewende* affects them negatively or very negatively. However, there seems to be a trend towards a more positive perception. The share of companies reporting a positive or very positive effect is rising, and the share reporting negative effects is declining (DIHK 2012, 2013, 2014, 2015). In 2017, the average assessment of *Energiewende* effects on competitiveness was very slightly positive.

Figure 11.7: Perception of *Energiewende* impacts on competitiveness (in per cent of company responses, 2012–2015)



Sources: DIHK (2012), DIHK (2013), DIHK (2014), DIHK (2015).
Note: Values not adding up to 100 per cent indicate missing or neutral responses.

The main reason for negative assessments seems to be price. While electricity stock market prices have decreased (see Figure 11.2), grid and renewable energy fees have increased. DIHK calculates that fees and taxes account for 81 per cent of electricity costs to those companies that are not eligible for price reductions (DIHK 2015). Energy security, which is crucial for the industrial sector, is seen as high.

It is unclear, however, whether companies see the '*Energiewende-Barometer*' report as a means to lobby government for lower electricity prices or further industry exemptions to the renewable electricity surcharge. Past attempts have been successful, and it would be in the interest of industry to see these exemptions prolonged and broadened. Currently, the industrial sector has to bear only 30 per cent of the surcharge, while it accounts for almost 50 per cent of German electricity consumption. Private households with an electricity consumption share of roughly 25 per cent have to bear 35 per cent of the surcharge (Lütkenhorst and Pegels 2014). In 2013, the electricity surcharge—the rise in electricity price attributable to the feed-in tariffs—for consumers who did not benefit from exemptions amounted to EUR 5.3 ¢/kWh, rising to EUR 6.24 ¢/kWh in 2014 (Lütkenhorst and Pegels 2014; Kemfert et al. 2015). In addition, exempted industries benefit from the decrease of the wholesale electricity spot-market price caused by increasing amounts of renewable electricity fed into the grid, the 'merit order effect' (Figure 11.2). The annual benefits from this effect are estimated at about EUR 500 million (Kemfert et al. 2015). A recent study on the competitiveness effects of energy price changes due to the *Energiewende* concludes that many energy-intensive companies offering premium products, such as high quality steel or aluminium, would be able to stay profitable when having to pay the renewable energy surcharge (Ecofys, Fraunhofer ISI 2015). However, many companies producing lower quality products, and thus having to compete globally on the basis of price, would face economic losses. These companies might in the medium term consider relocation to other countries if they had to pay the full surcharge. It should be noted, however, that companies' locational decisions depend on many additional factors, including network effects and proximity to consumers. Nonetheless, the study comes to the conclusion that in total the exemptions have a positive net effect on the German economy. Using a macroeconomic model, the authors estimate an average increase in production costs of 3.5 per cent in 2020, were all exemptions abolished. Positive effects from cost relief of households and currently non-privileged industry would not suffice to outweigh the negative effects on the economy: Exports in 2020 would be 0.3 per cent or EUR 4.7 billion lower than in the reference case with current exemptions, and GDP would be 0.15 per cent or EUR 4 billion lower (Ecofys and Fraunhofer ISI 2015).

4.3. VALUE ADDED

If data indicating innovation or competitiveness needs to be treated with care since the boundaries of the category 'clean energy technologies' are not clearly defined, this caveat is even more relevant in the case of value added. Not only is it necessary to draw technology boundaries, but also boundaries between economic activities.

This may be one reason why only a few studies exist on the *Energiewende*'s effects on value added in Germany, and why they mostly concentrate on renewable energies as a relatively clearly defined technology group. Two such studies merit particular attention, Aretz et al. (2013) and Prognos (2015).

Aretz et al. (2013) calculate value added in Germany in 2012 by renewable energies, including wood fuel, heat grid, heat pump, solar power, bioenergy, deep geothermal, hydro power and wind energy. In addition to municipal value added they calculate tax revenues at state and federal levels, and they calculate direct as well as indirect effects from upstream activities by using an input-output model. Direct value added comes to EUR 16.9 billion, EUR 11.1 billion of which accrue to the municipal level. Of the remaining EUR 5.8 billion, EUR 4.5 billion are federal and EUR 1.1 billion state taxes.

In terms of value added along the value chain, the operation-related steps of plant and system operation and maintenance contribute the largest share with a total of EUR 8.0 billion, or 47 per cent of total value added. They are followed by systems and components manufacturing with EUR 6.6 billion, and planning and installation with EUR 2.3 billion.

Indirect value added by upstream activities add another EUR 8.5 billion in 2012, EUR 6 billion of which accrue to the municipal level, with the rest accruing to federal and state levels. Total direct and indirect value added thus adds up to EUR 25.4 billion. About EUR 16 billion stem from wind and solar energy.

Prognos (2015) calculates value added for the entire German energy sector. In 2011, a total value of EUR 68 billion was added by the conventional and renewable energy industries. EUR 5 billion are directly attributable to renewable energies, EUR 15 billion to conventional energies. The remaining EUR 48 billion, mostly added in the value chains of electricity and district heating, cannot be directly attributed.

Compared to conventional energies, the value added by renewable energies calculated by Prognos (2015) seems to be low. One reason is the relation of forecasted investment cost and operation cost of renewable energies. Most renewable energies, such as solar or wind energy, do not require constant fuel inputs. They are, however, capital-intensive. Compared to conventional energies, a higher share of value added is therefore generated in the installation phase. Another reason is the conservative calculation method applied by Prognos, only considering clearly attributable value added for the group of renewable energies. Value added in the statistical category for *Energieversorgung*, or energy supply, is allocated to the group of conventional-renewable energy mix. With EUR 45.8 billion, this category contributes the main share to the non-attributable group, and indeed to total value added in the energy sector. With more fine-grained statistical methods, part of this value added could be attributable to renewable energies. When taking the share of renewables in the electricity mix in 2011, which was 25 per cent, as a proxy for the share of renewables in the value added of the mixed category, the total value added of renewables in Prognos (2015) would correspond to about EUR 16 billion, which is comparable to the value calculated by Aretz et al. (2013).

4.4. EMPLOYMENT AND INCLUSIVENESS EFFECTS

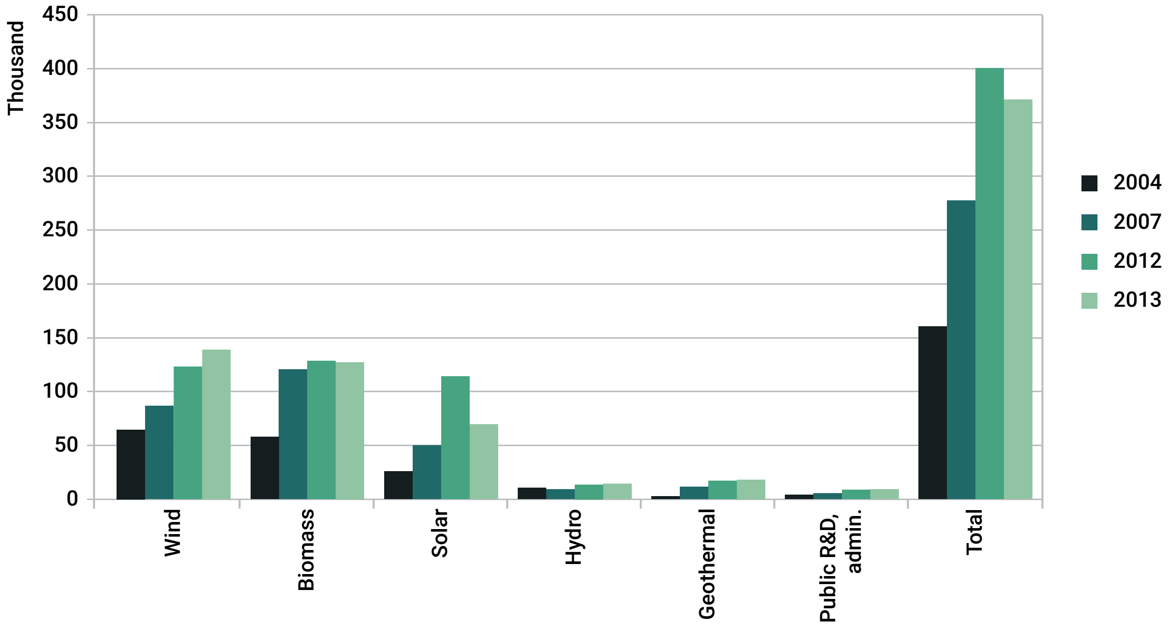
Distinguishing employment effects due to clean energy technologies is another difficult task, similar to the problems with value added (Haider et al. 2017, this volume). Accordingly, most studies refer to renewable energies. Study results vary with the methodologies applied, in particular with the consideration of indirect employment effects in upstream sectors. An overview of the results of three recent studies on employment created in the German renewable energy sector offers possible insight (Table 11.2).

Table 11.2: German gross employment in renewable energies, overview of study results

Study	Aretz et al. (2013)	Lehr et al. (2015)	Prognos (2015)
Gross employment	166,000 in 2012, only direct effects	371,400 in 2013, direct and indirect effects	104,000 in renewable energies in 2011; a further 293,000 not clearly attributable to conventional or renewable energies

Lehr et al. (2015) provide a valuable overview of job developments from 2004 to 2013 (Figure 11.8). While the number of people employed in the different renewable energy technologies grew considerably from 2004 to 2012, it declined in 2013. This is almost entirely attributable to job losses in the solar photovoltaics industry. While the number of people employed in solar cell manufacturing nearly halved in 2013, employment in the other technologies remained relatively constant or increased.

Figure 11.8: German gross employment in renewable energies, 2004–2013

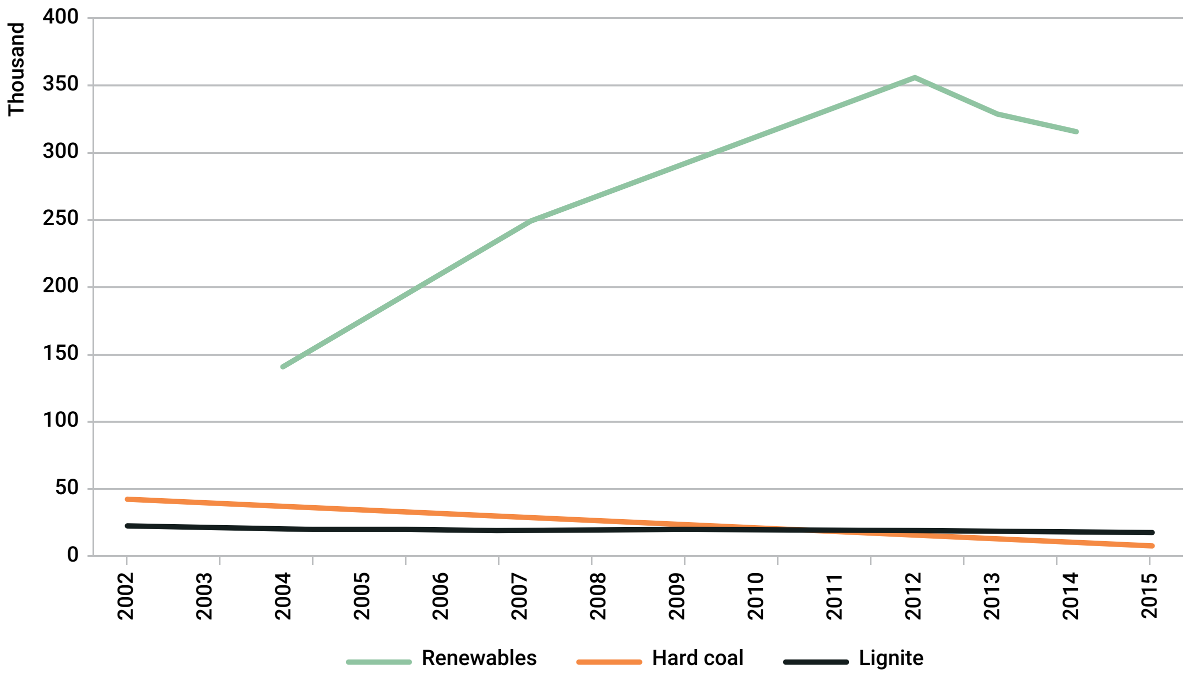


Source: Lehr et al. (2015).
Note: Values for 2013 are estimates.

Nestle et al. (2016) contrast total employment created by renewable energies with total employment created by the German coal industry. Their analysis indicates that renewable energies create considerably higher numbers of jobs, despite recent job losses in the photovoltaic industry (Figure 11.9). Furthermore, it shows declining employment numbers in German hard coal mining.

However, the results of the comparison strongly depend on attribution methodology and industry boundaries. Prognos (2015) calculate a total of 140,000 jobs created by conventional energies in 2011, including jobs in hard coal, lignite, natural gas and mineral oil products, as compared to 104,000 jobs clearly attributable to renewable energies.

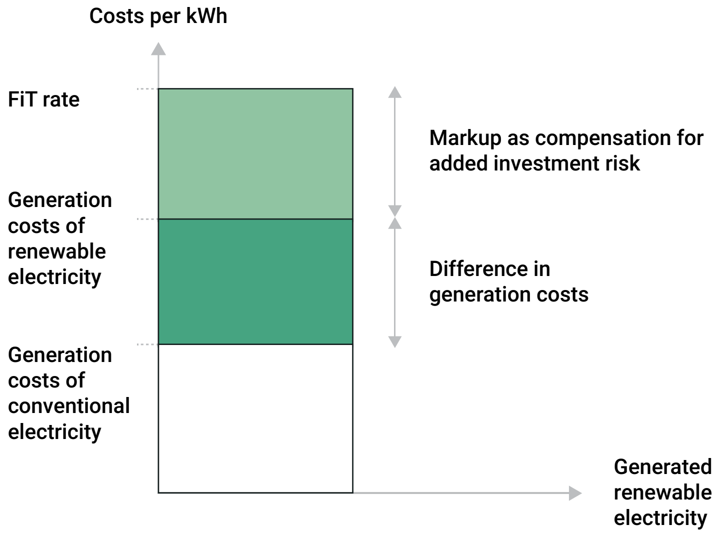
Figure 11.9: Employment in renewable energy and coal industries, Germany, 2002–2015



Source: Adapted from Nestle et al. (2016: 9), data from Lehr et al. (2015), O'Sullivan et al. (2015), Statistik der Kohlewirtschaft e.V. (2016a), Statistik der Kohlewirtschaft e.V. (2016b).

When assessing the effects on inclusiveness, not only employment effects but also households' price increases merit consideration. These are increasingly causing concern in the German case, and the distribution of additional costs of the *Energiewende* has become subject to a heated debate. The principal idea of the German support scheme is to subsidise renewable energy technologies by adding a surcharge to the price of electricity. This surcharge entails a net cost factor and a distributional factor (Figure 11.10).

Figure 11.10: Feed-in tariff components



Source: Anna Pegels.
Note: The areas do not reflect the actual size of cost components.

This differentiation is essential, although it is not always made explicit in the literature. The additional net costs arise from the fact that electricity production from most renewable sources is still more expensive than from conventional sources. These costs can be measured as the difference between the levelized cost of electricity generated from renewable sources and the levelized cost from non-renewable sources. If a feed-in tariff is to induce investments in renewable energy, it needs to cover these additional costs plus a reasonable markup as compensation for the added risks of such investments. The risk markup, however, does not add to net macroeconomic costs. It is rather a re-distribution of funds from electricity consumers to producers of renewable electricity. The surcharge thus includes an additional component that cannot be counted as net macroeconomic costs–the hatched area in Figure 11.10. In the case of Germany, the re-distributive effects are reinforced by the exemptions granted to energy-intensive enterprises, which raise the burden on the remaining consumer groups. These groups include households and most small and medium enterprises, which are not beneficiaries of the exemptions. The number of German households and enterprises that have been cut off their electricity supply for payment default has been rising from about 312,000 in 2012 to about 350,000 in 2014, indicating rising energy poverty (Bundesnetzagentur and Bundeskartellamt 2015). There is a trade-off between the protecting the competitiveness of energy-intensive industries on the one hand and the competitiveness of non-exempted enterprises and distributional effects for households on the other hand.

5. LESSONS LEARNED AND REMAINING CHALLENGES

The *Energiewende*–with its facets of renewable energy and energy efficiency in electricity, transport and heating–is a comprehensive and complex undertaking. Regarding the official *Energiewende* targets, Germany has made considerable progress particularly in the deployment of renewable energies for electricity generation, while other areas, such as energy efficiency, are lagging behind expectations.

It is not possible, however, to clearly categorise the *Energiewende* as successful or unsuccessful industrial policy. The answer crucially depends on the analysed section of industry. Renewable energies provide the most accessible and comparable databases, which is why this chapter mostly concentrates on them and takes other technologies only as complementary, although somewhat anecdotal, evidence.

In renewable energy technologies, Germany has been partly successful in building innovative advantages. Although competition by emerging economies is increasing, it was able to build on its strong technological capacities to create an innovative edge. In wind energy it has succeeded in gaining considerable global market shares, but the picture for solar photovoltaics is less inspiring. A stronger focus on sophisticated steps in the global value chain may have proven effective in avoiding bankruptcies and job losses in the photovoltaic cell industry. While Germany persistently ranks high in the Global Competitiveness Index of the World Economic Forum, indicating no negative overall impact of the *Energiewende*, companies in sectors other than clean technologies take a critical stance towards the policy's repercussions on their competitiveness. They attribute electricity price increases to the *Energiewende* and express concerns about the security of electricity supply.

In terms of value added, renewable energies are becoming an economic factor in municipalities as well as in the form of state and federal taxes. While renewable energies create considerable employment, these positive effects are at least partly countered by job losses in conventional energies. An estimate of net employment effects is challenging, since available data often does not allow clear attribution: first, drawing clear boundaries to clearly define relevant sectors is a challenge in itself, and second, available data is not yet sufficiently fine-grained.

Alongside job effects, the distribution of additional costs and the impacts on energy poverty are central to assessing the inclusiveness dimension of the *Energiewende*. The fairness of cost distribution in Germany has indeed become an issue of vigorous public debate. The distributive effects are reinforced by exemptions from the electricity price markups granted to energy-intensive enterprises. These exemptions raise the burden on the remaining consumer groups, including households and non-privileged small and medium enterprises. The resulting price increases contribute to energy poverty: the number of electricity payment defaulters has been rising recently.

While effects on electricity access are not relevant in the German case–electricity access is at 100 per cent–they can be a particularly important aspect of inclusiveness and a major policy aim in developing countries, particularly in Africa. Average African electrification rates are at 43 per cent, but considerably lower in rural areas, where they average 26 per cent (IEA 2016). In Sub-Saharan rural Africa they average only 17 per cent. Renewable energy off-grid solutions can make valuable and cost-efficient contributions to electrification, particularly in remote rural areas.

When interpreting the above assessment, two caveats are in order. First, such economic effects as reduced health costs from improved local air quality, avoided costs from climate change mitigation and other factors do not enter into the picture. Second, the above assessment can only provide a snapshot and neglects dynamic and secondary effects, such as technological spillovers that could be expected from a smart grid, innovative materials or energy storage technologies. Positive economic effects of renewable energies are thus likely to be underestimated, particularly in the longer term. Furthermore, the effects of the German *Energiewende* as an inspiration for other countries' energy policies, and subsequent global technological progress in renewable energies, are considerable. The Chinese success in building a highly competitive solar photovoltaic industry has led to stark declines in photovoltaic technology costs and thus to a virtuous cycle of scale economies and technology diffusion. The phenomenon is partly based on German pioneering of photovoltaic technology. However, the detailed analysis of international competitiveness effects is beyond the scope of this chapter.

Despite these caveats, the German case provides a wealth of experience and lessons. Success factors, barriers, and subsequent policy amendments will be discussed below, including implications for–and lessons from–developing and emerging countries.

Three fundamental principles established in *Erneuerbare-Energien-Gesetz*, the German renewable energy law, can be considered the basis for the establishment of renewable energy industries and for the rapid growth of renewable energy capacity in Germany, while safeguarding competitiveness of industries other than renewables. These principles are:

- Energy source-specific feed-in tariffs covering a 20-year time horizon
- Grid connection, transmission and distribution priority for electricity supplied from decentralized renewable energy sources
- Burden sharing of additional costs by all electricity consumers through an electricity price surcharge, with exceptions in particular for energy-intensive manufacturing enterprises.

Until the renewable energy amendment in 2014, the feed-in tariffs for renewable energy sources were guaranteed and fixed, constituting a purchasing guarantee for unlimited volumes. This provided unprecedented investment security for project developers and, combined with rapid cost digression especially for solar photovoltaics, led to strong growth of renewable energy industries and national installed capacity. However, while only some industries could firmly establish their competitive edge, capacity growth increased the cost burden on consumers, which led to criticism of the scheme. The inflexible feed-in tariff rates and windfall profits of the *Energiewende's* early years are a reason why the total policy costs are not a suitable orientation for similar policies in other countries: on the one hand, technology costs have considerably decreased, and on the other hand, policies themselves have become more efficient. The renewable energy amendment of 2014 reacted to the increasing cost of the *Energiewende* by establishing technology-specific, yearly caps for additional capacity (Deutsche Bundesregierung 2014). In addition, the government took the decision to change the determination method for feed-in tariffs from pre-determination to tendering. Following a pilot tender for large solar photovoltaic installations in 2015, this method will take effect from 2017 for 80 per cent of new wind and photovoltaic installations (BMWi 2015c). To avoid a competitive disadvantage for small-scale installations, those smaller than 1 MW are exempted from the tendering requirement. In turning to competitive elements in the support of renewable energy, the German government follows the example of many emerging countries, such as China, India and South Africa. These countries have successfully experimented with tendering schemes and have gathered a wealth of experience in the technical design of efficient and effective feed-in tariffs (Pegels 2014). Lessons learned from these countries include the integration of a systematic policy learning process through successive amendments of the scheme in the course of various bidding windows; the integration of safeguards against adventurous bidding, such as penalty payments in the case of project defaults; and the integration of measures to secure local economic and social benefits, such as domestic content requirements and social development requirements for the eligibility of projects for support.

Guaranteed grid connection and transmission and distribution priority for German renewable energy provide further investment security, since project developers can be sure that the generated electricity can be fed into the grid and sold at the feed-in tariff rate. Grid connection can otherwise constitute a major barrier for the feasibility of renewable energy projects, in particular when it needs to be implemented by an actual competitor of the renewable energy project developers. This is the case in many developing countries where electricity supply and grid operation is in the hands of state-owned and often monopolistic companies. These companies face a conflict of interest when obliged to undertake grid investments to connect their competitors. Morris and Martin (2015) describe the South African state-owned enterprise Eskom to show behaviour that can be interpreted as 'malicious compliance'–not actively opposing the government's renewable energy policies, but using its own control over the electricity value chain to obstruct independent power producer engagement. Public opposition, too, can constitute a barrier to grid expansion. While fossil fuel power plants can be built in close proximity to centres of electricity demand, renewable energy capacity needs to be located at favourable generation sites. This necessitates transmission lines to bring the electricity to centres of demand. Between 2013 and 2015, 72 to 78 per cent of respondents to the *Energiewende-Barometer* surveys saw grid expansion as the main priority of German energy policy in the context of the *Energiewende* (DIHK 2013, 2014, 2015). The construction of transmission lines, however, can be in conflict with local residents' interests. Building the lines below ground is one option to mitigate such conflicts, but it is considerably costlier than building them above ground. In their agreement of 01 July 2015 on the *Energiewende* implementation, the chairpersons of Germany's ruling parties nonetheless stipulated that underground cables will be favoured in the planning of new high voltage direct current transmission lines, thus hoping to increase the chances of public acceptance (BMWi 2015b).

Where competitiveness concerns forestall assignment of the additional costs of such measures to eligible industries, these costs will increase the electricity price for non-eligible consumers, thereby increasing the risk of energy poverty. These effects can constitute a barrier to public acceptance of feed-in tariff schemes, especially in developing countries. Where social security systems fail to cushion those effects, additional compensation for people living in poverty needs to be implemented.

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CHAPTER 12

ELECTRIC MOBILITY AND THE QUEST FOR AUTOMOBILE INDUSTRY UPGRADING IN CHINA

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1. INTRODUCTION

China promotes an ambitious electric mobility programme, with two main objectives: to reduce urban air pollution and to enhance the competitiveness of its national automotive industry. A range of industrial policies is being applied, and several pathways to electric mobility are being explored in parallel. On the one hand, China's industrial policy promotes the development of battery-electric and plug-in hybrid passenger cars, buses and trucks using a wide range of subsidies and regulations. In addition to encouragement of public and private Chinese carmakers, the government puts pressure on international investors to co-develop modern electric cars in joint ventures with their Chinese partners. On the other hand, in the shadow of national industrial policy and with very little government support, low-cost electric vehicles experience an unprecedented boom. These include the 200 to 230 million electric two-wheelers now circulating on China's roads and the recent addition of simple low-speed electric cars. Although the latter are not permitted on highways, their popularity in rural areas is enormous, with 600,000 produced in 2015 in Shandong Province alone.

This paper explores the direction of the electric vehicle industry's evolution and the extent of China's ability to achieve its environmental objectives, while at the same time reaping early mover advantages in an emerging global industry. Section 2 informs the reader about the current technological shift from internal combustion engines to electric automobile technology and how this may affect the competitive positioning of countries and companies globally. Section 3 discusses China's objectives, highlighting two: enhancing national competitiveness in the automobile industry and reducing urban air pollution. Section 4 provides an overview of China's most important electric vehicle policies, revealing an enormous political commitment for this transition. Section 5 takes stock of where China stands in terms of technological achievements and emerging competitive advantages, differentiating the four main technological areas of high-speed cars and buses, low-speed cars, two-wheelers and battery manufacturing. Section 6 then discusses to what extent these developments actually address the environmental problems related to the automobile industry. Section 7 summarizes the technological and environmental achievements of China's move towards electric mobility.

2. FROM INTERNAL COMBUSTION ENGINES TO ELECTRIC DRIVING: A TECHNOLOGICAL PARADIGM SHIFT

Globally, road transport is at the beginning of a technological paradigm shift. According to international scenarios, transport in urban areas has to be largely decarbonised by 2050 to keep global warming within manageable limits (Teng et al. 2015). The old technology of internal combustion engine automobiles is incompatible with the imperative of decarbonising the world economy. New carbon-efficient transport technologies are required and electrification is the most prominent alternative option, provided that the electricity used by cars comes from low-carbon energy sources. Furthermore, in contrast to conventional traffic, electric vehicles produce almost no local emissions and therefore reduce air pollution in the cities.

Electric vehicles include a range of different transport technologies, including electric ships, trains, buses, cars, and two-wheelers. The focus here is on cars and two-wheelers, given the enormous economic importance of the respective industries, as well as their huge environmental impact.

Cars and two-wheelers can be fully or partly electrified. In a fully electrified battery-electric vehicle, the internal combustion engine is replaced with an electric engine powered by a huge, in most cases lithium-ion, battery. There are, however, different intermediate stages of hybrid vehicles that combine electric and fuel-engine driving. Mild hybrids are propelled mainly by internal combustion engines—they use batteries as a complementary temporary power source. Batteries recharge with the electricity generated by the combustion engine and the energy recuperated from braking. Such vehicles can drive on electric only in the short term and their range is very limited. Plug-in hybrids are designed for electric propulsion and have only a small auxiliary combustion engine. They use larger batteries that can be plugged into the electricity grid.

Electric passenger cars, defined as fully battery-electric vehicles and plug-in hybrids, still account for only a small share of the global car market: in 2016, 0.2 per cent of all passenger cars (OECD and IEA 2017). In the market segment of two-wheelers, the world market share of electric motors is much higher, about 25 per cent, a proportion almost exclusively due to the popularity of electric bikes and scooters in China (OECD and IEA 2016). Overall, electric vehicle deployment has been held back by technological problems, mainly the disappointing performance and high price of batteries: Most electric vehicles can travel only 100–200 miles without recharging and fully recharging a battery takes 4–8 hours. Progress on these fronts however is quickening. Battery performance is improving, particularly in terms of the possible driving range, and their cost has decreased rapidly in recent years, from US$ 1,000 per kWh in 2010 to US$ 300–400 per kWh in 2014 (Nykvist and Nilsson 2015). These authors forecast that the price will go down to US$ 200 per kWh by 2020 and calculate that electric vehicles will become cost competitive with conventional cars at a price of US$ 150 per kWh. In the same vein, a recent study by Bloomberg New Energy Finance (2016) states that battery price reductions "will bring the total cost of ownership of electric vehicles below that for conventional-fuel vehicles by 2025, even with low oil prices." At that stage, uptake is likely to accelerate very fast. The same source predicts that sales of electric vehicles will reach 41 million by 2040 and include 35 per cent of light duty vehicle sales. This is nearly 90 times the equivalent 2015 figure, when electric vehicle sales may have reached 462,000, about 60 per cent more than 2014 (Bloomberg 2016). In fact, global car manufacturers have already begun a race for new and higher-performance battery-electric and plug-in hybrid models.

At the same time, political pressure to electrify road transport is increasing, as countries committed to ambitious decarbonisation agendas in the 2015 Paris Agreement. Even before that, many OECD countries had defined roadmaps for the gradual reduction of GHG emissions that force carmakers to successively reduce their average fleet emissions. The European Commission requires carmakers to ensure average emissions of their fleets do not exceed a maximum of 130 g CO_2/km for newly registered cars in 2015, and this threshold will be lowered to 95 g CO_2/km by 2021. Although further reductions have not yet been specified, the regulations ask "the Commission to maintain a clear emissions-reduction trajectory comparable to that achieved up to 2020" (EC 2017). United States and Japanese authorities have set similar targets. Physical limits to fuel efficiencies in combustion engines mean they cannot be fully decarbonised (Ferguson and Kirkpatrick 2015). Since the required reductions cannot be achieved by improving combustion engines, carmakers must substantially increase the share of hybrid and electric vehicles in their fleets. In China, political pressure for electrification is similarly high, although for a different reason. Chinese cities suffer unbearable air pollution and, given the combination of strong public discontent with air pollution and a massive increase of car ownership, reducing car-based pollution is a political top priority.

The automotive industry is one of the most important manufacturing industries globally. In 2015 it produced 68.5 million passenger cars and 90.7 million buses and trucks, with the corresponding employment benefits (OICA 2016). In the EU, for example, 2.3 million people were directly employed in car manufacturing in 2014, increasing to 12 million if related services are included (ACEA 2016). A similar order of magnitude applies for the United States and China. The car industry creates important secondary effects in industries such as steel, machine tools, electronics and chemicals, explaining why all major developing countries try to create domestic automotive industries as a backbone of their national industrial development strategies. At the same time, the minimum scale requirements and technological sophistication of the automotive industry have continuously increased over the past decades. Since South Korea joined the exclusive club of car-producing nations in the 1970s, not a single newcomer has been able to catch up with the technological frontier. China, India and other emerging economies are quite successful in producing cars and two-wheelers for their domestic markets, but none of them has been able to seriously challenge the technological leaders, so far.

The paradigm shift to electric driving will likely cause a major industry shake-up. When a new set of technologies and the necessary supporting institutions emerge, much of the accumulated knowledge and physical assets accumulated by incumbents loses its value, making it much easier for newcomers to compete (Perez 1988). Battery-electric vehicles require different kinds of auto parts: electric engines with integrated powertrains, magnets, powerful traction batteries, different power electronics, new software, inverters, charging devices, new lightweight materials such as carbon fibre-reinforced polymers–and totally different thermo management systems because there is no combustion engine that can be used for heating and cooling. Conversely, combustion engines and their parts, such as pistons, crankshafts and alternators as well as exhaust systems and fuel tanks, will no longer be required. As a result, supplier industries are likely to go through a major restructuring and see the emergence of newcomers to the auto industry (McKinsey & Company 2011). Similarly, the architecture of electric cars can be radically different: The combustion engines are no longer needed, but heavy batteries need to be placed in the auto bodies in ways that allow for good driving performance. Electric vehicles can have centrally placed electric engines, but there may also be two motors attached to the front and rear axles respectively, or four small motors placed in the wheels (e-mobil BW 2010). Chassis can be made of carbon fibre rather than steel. All these changes challenge the existing carmaker's competitive advantages, which are currently rooted in their capabilities to master internal combustion engine and transmission technology, to design cars and to manage multi-tiered production networks.

In fact, worldwide, many firms from non-automotive backgrounds are now venturing into electric vehicle manufacturing, trying to take advantage of the techno-organizational change to leapfrog into the car industry. The concept of leapfrogging refers to newcomers adopting a new technology more quickly and thereby overtaking the formerly leading firms (Fudenberg et al. 1983). Tesla, a complete newcomer to the automotive industry based in California, started production of an all-electric sports car in 2005 and within a few years leapfrogged into the segment of leading luxury carmakers. Between June 2012 and September 2017, it sold almost 200,000 Model S luxury vehicles and the company aims to deploy at least 1 million electric cars by 2020 (OECD and IEA 2017).

Other, albeit not yet equally successful, newcomers have sprung up in other countries. In China, BYD and Zotye were the first movers in producing electric cars in China–each arriving from a different industry background. BYD was a battery manufacturer that ventured into car manufacturing by 2003 and Zotye was an auto-parts dealer that began producing cars in 2005. Both started with traditional internal combustion engines but took up electric vehicle production earlier than the established carmakers. At a national scale, China's aim is to take advantage in a similar way. With a strong effort to become a leading manufacturer of electric vehicles, as well as a leading market for them, the Chinese government hopes to become more successful in the global car industry than it was in the era of combustion engines.

3. CHINA'S OBJECTIVES: ENHANCED COMPETITIVENESS AND CLEANER URBAN AIR

China is one of the most ambitious promoters of electric mobility and, clearly, the most important one outside the OECD. China promotes electric vehicles for various reasons, but two stand out.

The first reason is that the country regards the technological shift from internal combustion engines to electric propulsion as an opportunity to catch up with the global leaders in automotive technology and production. Although China's automobile production goes back to the early years of the People's Republic of China, the industry took off only in the 1990s after being declared officially strategic for China's economic development. Car production was seen as a cornerstone of technological development and national policies aimed at indigenous innovation (Chu 2011). China's provinces tried to create state-owned automobile companies with local supplier networks (Thun 2006).

Since private car ownership was allowed, sales and production soared. China has by far the largest market in terms of passenger car sales worldwide (Euler Hermes 2014). In 2015, China produced 21 million passenger vehicles (OICA 2016). However, technological progress has been slow and foreign brands still capture almost 60 per cent of the Chinese market (EU SME Centre 2015). Fuel engines and transmissions are among the technological fields where China clearly is behind international competitors; but these technologies are not needed in battery-electric vehicles. At the same time, electric engines are less complex and less expensive. Finally, China has the second largest reserves of lithium in the world and is a leading global manufacturer of lithium-ion batteries, so there seems to be a solid basis for seizing this opportunity. For these reasons, policymakers are optimistic that China's industry can take advantage of the technological change and, leapfrogging into the era of electric mobility, become a leading player in the global automotive industry (Wang and Kimble 2011).

The second reason for shifting to electric vehicles is that they are emission-free locally and therefore promise a solution for urban air pollution–one of China's most pressing problems. Concentrations of particulate matter in big Chinese cities are far beyond what the World Health Organization considers safe, and respiratory health problems are among the main causes of death. Zheng et al. (2015) estimate that every year between 2001 and 2012 in Beijing's central area, over 5000 people died prematurely due to increased PM2.5 concentrations.[27] Estimates on the costs of health attribute US$ 1.4 trillion losses to outdoor air pollution in China in 2010 (OECD 2014). It is difficult to isolate how much of this cost is due to road traffic, but for Beijing it is estimated that in 2013 motor vehicles accounted for 21 per cent of PM2.5 and estimates for Shanghai 2014 attribute 22 per cent to motor vehicles, ships and airplanes (Beijing Municipal Environmental Protection Bureau 2014; Shanghai Municipal Environmental Protection Bureau 2015). This share is likely to increase with the globally unprecedented boom in combustion engine car sales in China. By 2015, the registered passenger cars in civil use surpassed 95 million, making China by far the world's biggest automobile market (National Bureau of Statistics of China 2016). Moreover, between 2004 and 2014, car sales increased by 11.4 per cent annually in China compared to 0.9 per cent in the US, 1.4 per cent in the EU and -0.5 in Japan (Gao et al. 2014). At such growth rates, urban air pollution clearly will become unmanageable without a radical change in vehicle technologies.

Therefore, notably, climate change mitigation is not the main rationale behind China's electric mobility programmes. In fact, China's grid-powered electric cars emit even more CO_2 than average petrol cars when life cycle emissions are calculated. This is because electric vehicle emission totals include those from the fossil fuels burned to produce that electricity. Also, emissions from the manufacture of electric cars are higher than those of conventional petrol cars. Taking these factors into account, electric cars would have a better performance in terms of CO_2 emissions, except in heavily coal-based economies such as China. In 2016, coal-fired power plants still accounted for more than 65 per cent of China's electricity demand (China Energy Portal 2017). As a result, based on 2009 data, grid-powered electric cars in China emitted 258 g CO_2e/km, equivalent to a fairly inefficient petrol car with a 9 l/100 km fuel consumption (Wilson 2013).

However, a new study suggests that China's coal consumption peaked in 2014, much sooner than scenarios had predicted. Intervening years are verifying the trend and while coal will remain the primary source of energy in China for the next decades, the declining trend may accelerate (Qi et al. 2016).

4. CHINA'S ELECTRIC VEHICLE POLICIES

China's electric vehicle policies are driven mainly by the desire to leapfrog into a new promising field of technological specialisation and the need to reduce urban air pollution. To achieve these goals, China's central government set ambitious targets for electric vehicle deployment: 500,000 cars to be sold by 2015 and 5 million by 2020 (State Council 2012). To encourage electric vehicle development and deployment, a wide spectrum of policies were enacted by the central government (Table 12.1). In addition, provinces offered their own policy packages, which in part added to the central government's incentives, but also pushed in different directions.

27 Particulate matter consists of microscopic parts suspended in the atmosphere. PM2.5 refers to particulate matter with a mean aerodynamic diameter of 2.5 µm. These are highly carcinogenic as they penetrate deep into lungs and blood streams.

Table 12.1: Main polices for the promotion of electric vehicles in China

Phase 1 (1990–98): Research and development and small-scale demonstration projects	■ First research and development projects for electric vehicles in the 8th and 9th National Key Technology Research and Development Programmes
Phase 2 (1999–2008): Scale up systemic research and development projects with small-scale local demonstration projects	■ Deployment of Cleaner Vehicles programme: city trials in 12 major cities ■ 10th National Key Technology Programme for electric vehicles: scale up research and development for electric vehicles by about factor ten
Phase 3 (2009–2012): Large-scale demonstration projects and first major incentive programmes	■ New Energy Vehicles declared strategic emerging industry ■ Ten Cities, Thousand Vehicles Demonstration and Deployment Programme: testing and subsidies for public fleets in 25 cities ■ Use of conventional motorcycles banned in major cities: totally in 13 and partially in 16 cities ■ Energy saving and New Energy Vehicles industry development plan 2012–2020: preferential treatment of electric vehicles ■ Subsidy policy for purchasing private electric vehicles in 6 pilot cities ■ Public procurement regulations and subsidies ■ 400,00 charging stations and 2000 batteries swapping station target
Phase 4 (2013–2015): New round of incentives, systematic policy for charging	■ Guidelines for New Energy Vehicles Deployment with refined incentives: purchase tax waiver, trade barrier removal, price regulation of electricity charging, infrastructure subsidy etc. ■ Pilot region expanded to 88 cities ■ National Plan for Charging Infrastructure
Phase 5 (2016–ongoing): Reduced subsidies, stricter performance standards	■ Phase out of subsidies by 2020 announced ■ Electric vehicle quota for carmakers announced ■ Stricter fuel economy requirements ■ A general ban on the production and sale of fossil fuel cars under study for the near future ■ Use of stricter technology standards and licensing policies to overcome industry fragmentation ■ Enforcement of technological and environmental regulations for low speed electric four-wheelers

Sources: Adapted from Xu and Su (2016), Zhang et al. (2014).

As a key element of electric mobility support, the 'Ten Cities, Thousand Vehicles' programme launched demonstration projects in 13 pilot cities in 2009 and added 12 more later. Public electric grid companies were told to build an infrastructure of charging stations for electric vehicles. In parallel, 29 major cities fully or partially banned the use of petrol motorcycles, thereby boosting demand for electric two-wheelers (ADB 2009). Later on, especially with the launch of the 'Energy saving and New Energy Vehicles industry development plan 2012–2020' generous incentives were offered for the whole country, including purchase subsidies and tax exemptions for electric vehicles as well as large dedicated research programmes with emphasis on lithium-ion battery research. Purchase subsidies are probably the most generous ones worldwide (Mock and Yang 2014; Altenburg et al. 2016). In addition to US$ 9,200 per car from the central government, regional governments offered additional cash subsidies and free vehicle registration. For the city of Shanghai, effective subsidies reached US$ 27,600 per vehicle (Wan et al. 2015). Public procurement was another key policy. The central and local governments purchased electric vehicles for government fleets and made their procurement mandatory for bus and taxi companies. However, local procurement policies come at a price. In many cases, local governments focused subsidies onto locally manufactured car brands, thereby blocking competition and creating a geographically fragmented industry (Zhang et al. 2014).

More recently, the government announced plans to phase out purchase subsidies by 2020 that motivated local governments and investors to adopt many electric vehicle projects but at the same time reduced automakers and battery suppliers motivation to develop higher-quality products (Bloomberg News 2016). Instead, the government is now augmenting pressure on carmakers to accelerate electrification. Since June 2017, new draft legislation imposes an electric vehicle quota on carmakers. By 2018, 8 per cent of all newly built cars should have an electric engine, going up to 12 per cent in 2020. Companies that fail to meet their quota would have to reduce their sales of conventional cars or purchase credit points from other carmakers. Whether the quota can actually be reached, however, also depends on supply-side constraints, such as technological progress and availability of charging infrastructure. Yet, such pressure clearly has a strong effect on company strategies, and various carmakers already announced new investments in electric vehicle manufacturing for the Chinese market, including Volvo and Ford (The Guardian 2017).

Furthermore, the government defined a roadmap with gradually increasing fuel economy requirements for conventional cars which by 2020 will be among the most ambitious worldwide. The Ministry of Industry and Information Technology even announced their work on a timetable to totally ban the production and sale of fossil fuel cars from a certain date (The Guardian 2017). Moreover, stricter technology standards and licensing requirements are imposed to consolidate the currently fragmented auto industry (Bloomberg New Energy Finance 2016).

In parallel, pressure is increased on foreign carmakers to share technologies. As China is by far the world's largest and most dynamic market for automobiles, all major global carmakers are keen to increase their market presence in China. China pursues a barter-type policy allowing international carmakers to build new or expand existing production facilities, but only if they bring in their latest technology and co-develop cars with local partners (Holmes et al. 2015). A development plan issued in 2010 clearly states that for any joint venture manufacturing key components of electric vehicles–such as batteries, motors and controllers–the Chinese partner must hold at least 51 per cent of the capital. Again, such requirements can only yield the expected results if local partners manage to enhance their absorptive capacity for the new technologies.

5. TECHNOLOGICAL ACHIEVEMENTS AND EMERGING COMPETITIVE ADVANTAGES

Within a few years, China has become a leading global market for electric vehicles. This section provides an overview of achievements in four different segments of the electric vehicle industry in terms of market development, technological upgrading and competitiveness.[28]

5.1. HIGHWAY-CAPABLE PASSENGER CARS AND BUSES

Sales of highway-capable battery-electric and plug-in cars and buses remained marginal until 2013, with less than 18,000 in total, leading some analysts to pessimistic forecasts and critical assessments of China's electric vehicle policy package (Wan et al. 2015). Since then, however, deployment powerfully took off, surpassing 330,000 vehicles in 2015 (Xu and Su 2016). At about 1.4 per cent, this is still a minor fraction of all car and bus sales, but the increase is impressive and indicates a real breakthrough for electric driving in China.

Purchases by bus and taxi companies are a major force for electric vehicle deployment, while individual consumers are still hesitant to buy highway-capable personal vehicles despite the enormous subsidies offered. So far, Chinese products range at the low end of technological complexity and do not meet the quality demanded on international markets (Bloomberg News 2016). To assess the potential for technological upgrading, a differentiated view of China's automotive companies is needed.

State-owned enterprises, especially those engaged in joint ventures with international carmakers, have benefited from booming markets for traditional vehicles with internal combustion engines. Therefore, they have had little incentive to enter the risky field of electric vehicles. When the large state-owned car companies finally entered electric vehicle production, not least to benefit from the generous government subsidies, they relied on retrofitting the internal combustion car models rather than developing models optimised for electric vehicle technology. Generally, their strength is in producing technologically unsophisticated, affordable cars. For example, one of China's best-selling electric vehicles, the

28 Information on specific car models and their technological innovations in this section has been collected from specialised press reports and company websites.

Chery QQ3EV, used cheap but environmentally harmful lead-acid batteries until production stopped in 2016. But Chinese producers can adapt: lithium cells power Chery's follow-up model, the EQ-S15EV.

Recently the government increased its pressure on international joint venture partners to launch electric vehicles in the country and share the relevant knowledge with Chinese firms. In response to this, several international carmakers, including Toyota and BMW, have recently developed battery-electric vehicles that fit Chinese market conditions and are in some cases exclusively produced for this market. How this will affect technological learning and competitiveness of Chinese firms is not yet clear.

While state-owned enterprises long remained hesitant to venture into electrification, some technologically ambitious newcomer firms in car production became electric vehicle pioneers. These include Zotye Auto, the auto-part producer that started to produce battery-electric vehicles in 2010 and initiated an interesting battery-swapping project with the State Grid Company in Hangzhou; and BYD, the battery producer for the electronics industry. BYD first moved into car battery production and then produced the first plug-in hybrids in 2008 followed by a battery-electric vehicle in 2010. In 2014, BYD launched the battery-electric model Denza, a car developed with Daimler in China and the first car Daimler ever developed outside Germany.

It is not yet clear which electric vehicle developments in China are most promising in terms of technological leapfrogging and international competitiveness. Chinese carmakers may successfully specialise in simple, no-frills low-cost electric vehicles that meet the needs of emerging global middle classes. However, based on a rapidly expanding internal market for electric vehicles, China could become the global platform where automotive multinationals develop and produce large portions of their electric portfolios, with minor or major contributions from their Chinese joint venture partners. Also, electric bus manufacturing could become China's field of competitive specialisation. The rollout of electric buses has been impressive, with more than 300,000 buses circulating in China in 2015 (OECD and IEA 2017). This provides economies of scale and potential early mover advantages. Chongqing Hengtong Bus Power System Co. Ltd., for example, has developed the world's first rapidly recharging battery-electric public bus.

5.2. AFFORDABLE LOW-SPEED ELECTRIC CARS

Hundreds of Chinese companies have started to develop technologically simple small low-speed, low-voltage, low-range electric cars. These cars are built for a top speed between 40 and 70 km/h, sufficient to drive in cities or rural roads, but these low-speed electric vehicles are not allowed on highways. Their driving range without refilling the battery is up to 70 kms, which is sufficient for most Chinese customers.

Low-speed electric vehicles are very cheap. Depending on their sophistication, they are sold at a price of US$ 2,000 to US$ 8,000. Hence the lowest cost low-speed electric vehicles are affordable for many households unable to purchase a new gasoline car, which start at around US$ 5,000 in China. The fact that low-speed models are exempt from registration adds to their attraction; some big cities impose quotas on the registration of automobiles to limit the number of cars circulating in their jurisdictions. Prices are so low for two reasons. First, designs are very basic. These vehicles run on simple 1.5 to 4 kW direct current motors, they use low-cost components, such as lead-acid batteries, and all non-essential features have been removed. Low-speed electric vehicles lack sophisticated battery management or motor control systems and in most cases do not meet basic safety standards. Second, manufacturers combine very simple low cost techniques, such as traditional stamping dies, with hi-tech elements, including three-dimensional laser cutting robots (Autoblog 2014).

The future of China's low-speed electric vehicle industry is unclear. Unlike highway-capable electric vehicles, the low-speed models do not receive any government support. In particular, customers are not entitled to receive any of the generous purchase subsidies offered for highway-capable cars. Quite the opposite: national traffic regulations discourage the emergence of this industry. Only some provincial governments, especially the one in Shandong, encouraged low-speed electric vehicle production.

Still, demand is high for simple and affordable cars for families in smaller cities and rural areas. Tapping into this demand, dozens of relatively small carmakers emerged particularly in Shandong province where 600,000 low-speed electric vehicles were sold in 2015. According to OECD/IEA (2017) estimates, three to four million low-speed electric vehicles were circulating in China in 2016. Policymakers had not expected this popularity. In fact, Shandong's industry had emerged in the shadow of national law. According to national law, low-speed electric vehicles were illegal until very recently, yet some provincial and municipal regulations provided for exceptions on certain roads. Only in 2016, the central government started to develop legislation to legalise and regulate low-speed electric vehicles (Paglee 2017). So far, many central and local government policies remain contradictory with regard to minimum speed requirements and phasing out lead-acid batteries, among other issues. Once this legal uncertainty is overcome the market is likely to receive an additional boost; by 2020, low-speed electric vehicles' annual sales are projected to reach about 2 million (OECD and IEA 2016).

5.3. ELECTRIC TWO-WHEELERS

China's market for electric two-wheelers is booming. Two-wheelers include electric bicycles–bikes with a small electric motor that still retain the ability to be pedalled by the rider–as well as more powerful scooters and motorcycles. Sales started gradually during the 1990s and by 2004 40,000 were sold (Cherry 2010). At around US$ 230 to US$ 290 for simple versions and US$ 650 for high-end versions, electric two-wheelers are affordable for many Chinese families (Fu 2013). To keep their cost low, Chinese e-bikes are generally low-tech and powered by lead-acid batteries. Only a small fraction of two-wheelers are equipped with lithium-ion batteries, which increase the cost by US$ 160 (Fu 2013). Also, electricity costs are low: The cost of powering a two-wheeler is about 0.2¢ per kilometer. Battery replacement amounts to about 1¢ per km, depending on the size of the battery and fluctuating prices. These estimates compare to an average of 8¢ per kilometer for cars and 3¢ per kilometer for motorcycles. An average bus trip costs 3¢ per kilometer as well (Cherry 2010).

Two policy decisions make electric bikes so popular: The government classifies electric two-wheelers–with pedals, a maximum speed of 20km/h and maximum weight of 40 kg–as bicycles, so riders do not need a driver's license or registration. As well, many city governments restrict conventional motorcycle use in their inner cities (Cherry 2010).

About 200 to 230 million electric bicycles were circulating in China in 2015, according to various sources, with 37 million produced annually (OECD and IEA 2016). This makes China by far the most important global market with a share of about 85 per cent (INSG 2014). About 2,600 licensed whole-vehicle manufacturers and assemblers existed in 2011, of which the 50 largest account for half of the production (Fu 2013). The bulk of production is sold in China, but an estimated 5 million electric bikes are exported, mainly to other Asian countries (INSG 2014). Electric two-wheeler production and maintenance thus became a major and unique industry in China, even though they are technologically quite unsophisticated. With this scale of market success, electric bikes are the first mass-produced and massively popular alternative-fuel vehicles in the history of motorised vehicles (Cherry 2010).

5.4. BATTERY TECHNOLOGY DEVELOPMENT

China-specific technological solutions are also being developed in the field of lithium-ion battery technology. Chinese module production is close to the international technological frontier, but the country lags far behind in the fields of battery chemistry, membranes and battery management systems. About 200 battery manufacturers are operating in China, but most cannot compete with global brands (Bloomberg News 2016). Technological mastery of battery management systems in particular is important to produce premium cars and to differentiate brands: each system needs to be specifically tailored to the energy requirements of each car; moreover, they are necessary to optimise battery performance and prevent failures. Specific research and development programmes have been established to build capacity, but reaching the level of global leaders will take time.

The lack of technological capabilities in battery technology has led to two China-specific developments: First, some Chinese companies, including the Chinese state-owned automotive manufacturer BAIC and Zotye, have built remote battery monitoring systems that allow them to monitor the status of entire car fleets in real time through wireless networks. Monitoring centres can then send messages to drivers assisting them to improve battery performance and avoid emergency situations. Compared to mature onboard systems, remote monitoring is clearly a second-best option, but it can substitute some of the functions of advanced battery management systems.

Second, Chinese firms are investing in battery swapping operations so cars can exchange their discharged battery with a charged one, rather than recharging their own battery. This, in principle, saves time and provides flexibility to the user. The practical problem is that only identical batteries can be swapped. However, carmakers design battery management systems to meet the specific requirements of each model, and swapping stations cannot hold stocks of all battery models. In Hangzhou, electric vehicle manufacturers, battery manufacturers and the State Grid Corporation of China set up a citywide battery swapping experiment with the State Grid Corporation owning the batteries. The experiment targets mainly taxis of the Zotye brand and bus fleets, which keeps the number of battery types manageable. Extending the experiment to other car brands will be quite difficult, however.

6. TO WHAT EXTENT DOES THE SHIFT TO ELECTRIC VEHICLES SOLVE ENVIRONMENTAL PROBLEMS?

The shift to electric vehicles has one big positive effect on the environment: Electric vehicles themselves produce almost no local pollutants, so they help to reduce the enormously harmful smog levels in Chinese cities.

In terms of greenhouse gas emissions, in contrast, China's efforts to promote electric mobility do not make any positive contribution, yet. As discussed, with China's current energy mix, use of an average electric car emits as much CO_2 as a fairly inefficient petrol car. This, however, will change over time. On one hand, petrol cars are becoming more fuel-efficient. On the other hand, China is undertaking considerable efforts to decarbonise its power sector: The government set the target for peak CO_2 emissions around 2030 and is committed to steadily reduce them afterwards and carbon intensity will decrease by 60 to 65 per cent below 2005 levels by 2030 (He 2014). China's coal consumption peaked in 2014, much sooner than scenarios had predicted, and will decline by degrees, even as coal remains the primary source of energy for the next decades (Qi et al. 2016). Thanks to the energy-saving targets established in the 2005–2010 11th Five-Year Plan, CO_2 emissions declined by 1.46 billion tons during that period (Teng et al. 2015). Between 2011 and 2015, the share of low-carbon sources grew from 19 to 28 per cent of the national energy mix (OECD and IEA 2016). Whether electrification of China's transport is good for the global climate will depend on the relationship between fuel efficiency improvements and the rate of electricity mix decarbonisation. Physical limits to fuel efficiencies in combustion engines mean they cannot be fully decarbonised (Ferguson and Kirkpatrick 2015). Therefore, over the long run, transport electrification is the only alternative for China.

The manufacture, use and disposal of batteries produce another major environmental problem. China has made electric driving affordable. But this has been achieved by using the lead-acid batteries that are very harmful for the environment, especially when they are not properly recycled. Nearly all two-wheelers and low-speed vehicles use lead-acid batteries, and even in the segment of highway-capable cars, Chinese firms offer cheap lead-acid versions. Electric two-wheelers contribute greatly to releasing lead into the environment, given that they require a new battery containing 10–20 kg of lead every 12–18 months (Cherry 2010). In Beijing alone, 30,000 to 50,000 tons of lead-acid batteries need to be recycled every year (Fu 2013). However, Chinese battery recycling is not well regulated and as much as a quarter or more of the used lead is not captured in the process (Cherry 2010). After frequent cases of lead poisoning in China, in 2011 the government decided to close 80 per cent of all the registered lead-acid battery production, assembly and recycling companies (Fu 2013).

Lithium-ion batteries are less harmful, but at this stage in the industry's growth they are too expensive for general use. As the technology matures, however, costs are decreasing quickly (Nykvist and Nilsson 2015). Government regulations will then have an important role in ensuring that manufacturers adopt lithium-technology as soon as possible and that lead-acid batteries are phased out. While lithium-ion batteries also present a number of environmental challenges, there is hardly any alternative to using this technology at a much larger scale (USEPA 2013). Progress on lithium-ion batteries is critical to increase the driving range of electric vehicles and decrease their cost, which in turn makes electric vehicles attractive to more customers.

Last but not least, rebound effects matter: As electric vehicles become cheaper and better, and the population grows and becomes wealthier, more consumers can afford more advanced technologies. People who used to pedal their traditional bicycles are shifting to electric bikes and scooters. People who used to drive electric two-wheelers start buying low-speed electric cars, and those who drove such cars in the past may now be able to purchase a comfortable highway-capable car. Cherry (2010) cites studies conducted in Shanghai, Kunming and Shijiazhuang cities showing that most electric bike users used to travel by bus or bicycle, and only a few substituted them for cars. Furthermore, as people become wealthier, they tend to travel longer distances. Even if the technologies in use become more resource-efficient and the share of renewables in the energy mix increases, the sheer expansion of modern vehicle ownership and mileage is likely to result in higher total emissions. Low-carbon strategies need to account for these potential repercussions. Still, complementary reforms are necessary, such as the promotion of public transport systems, as well as urban designs that minimise the need to commute between housing areas, business districts and shopping centres.

7. CONCLUSIONS

China's ambitious programme to electrify road transport is an exemplary case of green industrial policy pursuing technological upgrading and greater competitiveness in parallel with environmental improvements. China's comprehensive policy package includes huge research and development efforts, technology-sharing agreements with global investors, strategic public procurement, purchase subsidies and city trials. The result is that electric-powered two-wheelers, passenger cars, trucks and buses are becoming a major alternative to fuels-based driving.

The Chinese government set hopes on electric vehicles as a technology that would allow the country to catch up with the global leaders in the automobile industry–something it had not achieved under the old paradigm of traditional combustion engine cars. Multinational carmakers maintained their significant advantage in combustion engine vehicle production through accumulated specialist knowledge in all the domains needed to build good engines and transmissions and to integrate them in the car design. However, manufacturing electric vehicles requires a different range of skills and, in principle, this will allow advantages for China.

China's leapfrogging aspirations are high, but the country has made significant progress in various domains:

- In the mainstream market of highway-capable electric vehicles many Chinese companies are now offering battery-electric and plug-in hybrid models. By international comparison, these are all still low-end, but they are also low-cost and suitable for the rapidly expanding domestic market.
- Some automobile multinationals are now producing new battery-electric models exclusively for the Chinese market. Given the size of the Chinese markets and government pressure to locate research and development operations in China, this may promote enhanced technological capabilities.
- In electric bus production, China has become one of the first volume manufacturers globally and should pursue this opportunity, especially to meet the demand from other countries for reducing urban air pollution.
- China produces 85 per cent of electric two-wheelers globally and exports about 5 million units annually to other Asian markets, although it only covers the low-end of markets, so far.
- Low-speed electric vehicles have emerged as an interesting niche market in which there is hardly any international competition because Chinese demand conditions are different from those in high-income countries. Offering such simple affordable products may be a viable business model for exports to other developing countries, especially as their decarbonisation efforts progress.
- China's industry has a long tradition at the level of lithium battery cell manufacturing and a strategic position due to its enormous lithium reserves.

So there are various promising opportunities for industrial development related to electric mobility. In all the technological fields mentioned above China has become a major player. The challenge lies in technological upgrading.

Across the board, Chinese producers cover the low-end product range, so far; whereas Japanese, Korean, European and American competitors cater to the more complex high-value vehicle market. But there is cause for optimism about the prospects for upgrading due to at least three reasons: First, the Chinese government has recognised the challenge and redesigned its policies with a stronger emphasis on research and development, stricter technology standards and consolidation of the fragmented auto and battery industries. Second, China is the largest market for most of the related supply chain products, giving the country an advantage in terms of scale of production as well as potential foreign direct investment. Third, exploiting the export potential of simple but reliable low-priced goods to countries with similar demand conditions is a promising option.

What about the hoped-for environmental improvements? After a few years of disappointingly slow uptake, a tipping point has now been reached where the share of electric vehicles in the Chinese fleet of two-wheelers, cars, buses and trucks is gaining traction. With each traditional fuel vehicle being replaced by an electric one, local emissions go down and, with enormous ramifications for public health, China's most pressing environmental problem, urban air pollution, is reduced. In terms of greenhouse gas emissions, the shift to electric vehicles will not improve the state of affairs in the short term. Instead, emissions will increase as electric vehicles run on power generated by coal-fired plants. But China's power sector is slowly shifting away from coal. As this trend continues and accelerates, the carbon footprint of China's electric vehicles is bound to improve. With a substantial share of renewables in the power mix, electric cars are clearly preferable to conventional cars. An integrated programme for greening the automotive industry must go beyond changes in the automotive sector and simultaneously pursue the decarbonisation of the electricity supply. Another problem lies in the increased demand for environmentally harmful but inexpensive batteries. Due to the preference for low-cost electric vehicles, the particularly harmful lead-acid batteries dominate the market. Gradual transitions to lithium-ion battery installation, as well as appropriate recycling policies, are needed to minimisrbe environmental harm.

Transition to sustainability requires complex systemic shifts rather than just technological substitutes. Policymakers need to ensure that the electricity mix gets decarbonised; that low-carbon public transport systems become more attractive; that cities are designed so people do not have long commutes between the places where they live, work and shop; and that materials are reused or recycled to the greatest extent possible. What inspires hope is the speed at which some countries, including China, are greening their economies and the realisation that emerging economies can reap the double dividend of environmental improvement and enhanced competitiveness.

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CHAPTER 13

ETHANOL POLICY IN BRAZIL: A GREEN INDUSTRIAL POLICY BY ACCIDENT?

Pedro da Motta Veiga, Sandra Polónia Rios

1. INTRODUCTION

Brazil pioneered policies to stimulate the consumption of renewable energy sources, providing incentives for the production of hydroelectricity and ethanol. Policies that foster the industrial transformation of sugar cane into ethanol gained attention during a period of strong economic growth in Brazil under the 1964 to 1985 authoritarian political regime.

The adoption of these policies was not due to environmental concerns, which were not widespread at the time. In fact, their implementation created considerable social and environmental problems, especially in the case of constructing large hydroelectric plants. Instead, the motivations for these policies in Brazil were directly related to limiting the rise of the oil imports after the oil price shocks of the 1970s and to mitigating the macro-economic impacts of any further shocks. In other words, the rationale for these policies related to energy security and to reduce the economic repercussions of growing oil imports. Nevertheless, due to these policies, Brazil now runs one of the world's most successful programmes for using renewable energies in its transport sector (Farina et al. 2013). Moreover, these policies have produced a high proportion of renewables in Brazil's energy matrix, more than 40 per cent in 2015, giving the country significant status in environmental and climate change negotiations (MME 2016).

Can these policies be considered 'green'? On one hand, they actually stimulated the supply and demand for renewable energy. On the other hand, analysis of these policies' implementation reveals a limited perception on the part of the government in any green dimension. This is particularly notable in the case of ethanol policy, which evolved in accordance with criteria and priorities only marginally related to green concerns.

This paper describes and analyses the case of Brazilian policies for the development of ethanol as a fuel competing with and replacing an oil derivative, gasoline. Brazil now has more than 40 years of experience with sectorial policies in this area, which involve policies aimed at the different stages of the ethanol's production chain. The antecedents and characteristics of the first phase of the ethanol policy adopted by Brazil in the 1970s are described in section 2. The second phase of the ethanol policy is the topic of section 3, which examines changes to the ethanol policies in the last decade and consequences for the sector's performance. Section 4 presents some policy lessons that can be drawn from the Brazilian experience with ethanol policies. Section 5 concludes.

2. THE FIRST PHASE OF THE ETHANOL POLICY: 1975 TO 1990

2.1. BACKGROUND

The production of sugarcane is one of the original large-scale commercial activities in Brazil, preceded only by extraction of the brazilwood that produces a red dye. Since the Portuguese colonization in 1500, Brazil has been one of the world's principal producers and exporters of sugar. However, since the 17th century Brazilian sugar met increased competition from nearby regions, principally the Antilles, and later from sugar beet produced in Europe, particularly at the end of the 19th century (Moreira 2008).

As a response, there were unsuccessful attempts to modernise the production of sugar in Brazil. Frequent crises of overproduction and the instability of prices led the federal government to intervene in the market at the beginning of the 1930s, creating the Institute of Sugar and Alcohol, in Portuguese, Instituto do Açúcar e do Álcool (IAA). According to Moreira (2008), IAA's state intervention took over the production chain, including the growing, commercialisation, price setting, and assigning quotas for production, exporting and associated imports with the explicit aim of balancing production and consumption in the sector. The IAA also sought to manage tensions and conflicts involving different regions and actors linked to distinct stages in the production chain. Decisions about productive capacity and its expansion, or about the destination of products, for example, were the responsibility of the IAA.

The first governmental measures aimed at encouraging the production and consumption of ethanol added to gasoline dated from the 1930s, establishing a proportion reaching 5 per cent of ethanol to be mixed with gasoline. The rationale for this measure was principally to reduce gasoline imports to Brazil.

Between the 1930s and 1960s, the sugarcane sector diversified geographically to the South East region around São Paulo, the most economically developed State in Brazil, and expanded productively with the growth of ethanol output. Until the end of the 1960s, the principal economic function of ethanol production, for the government and for producers, was to avoid oversupplying sugar and depressing its prices.

2.2. PROÁLCOOL: DEVELOPING A NEW INDUSTRIAL SECTOR

The strong rise of international oil prices at the beginning of the 1970s led to a radical change in the role of ethanol in the national economy. Brazil had been going through a period of accelerated economic growth driven by an expansion of the production and consumption of industrialised goods. Among the industrial sectors that emerged, automobile production stood out, as did its significant and growing dependency on oil imports. With the sudden increase in oil prices, between 1973 and 1974 the value of fuel imports jumped from US$ 600 million to more than US$ 2 billion (Moreira 2008).

Given the new scenario and the anticipation that oil prices would remain high, the federal government created the National Alcohol Programme, Proálcool, in November 1975. Concerns with the rapid deterioration of the trade balance, and the macro-economic repercussions, were at the root of the decision to create Proálcool. However, sectorial pressures to alleviate problems of excess production of sugar and the instability of the prices of this product also contributed to accelerate the government response to the new scenario. For Meyer et al. (2012), the Proálcool programme "was intended to both reduce Brazil's dependence on imported oil and make use of idle capacity in the sugar industry by converting sugar to ethanol."

The aims of Proálcool were linked to the logic of import substitution, which commanded Brazil's industrialisation strategy, not only because it aimed to replace oil imports. The strategy also intended to develop internal suppliers of capital goods for the sugar and ethanol industry. As noted by Moreira (2008), although the programme was not restricted to producing ethanol from sugarcane, this did become the principal raw material for ethanol production. Compared to alternative raw materials, sugarcane presented better marketing conditions, high availability, and short-term expansion potential.

The instruments used by the programme were diverse and supported by extensive government subsidies (Box 13.1). The government made subsidised lines of credit available for investment in both crops and industrial application, maintaining a balance between the prices of sugar and alcohol to eliminate a deciding factor when producers chose either sugar or ethanol, as well as guaranteed purchases (Moreira 2008). At the same time, a consortium of both public and private research institutions worked to improve sugarcane varieties (Meyer et al. 2012).

Box 13.1: Proálcool era: mid 1970s to mid 1980s

Context: During this period, the State had the monopoly of oil exploration and production and the control of prices of all types of fuel.

Main policy instruments:

On the demand side:

- Reduction of taxes on the purchase and sale of alcohol powered automobiles
- Establishment of a limit price of ethanol at 65% of the price of gasoline
- Increase of the compulsory mixing to 22% of anhydrous ethanol in gasoline;
- Tax incentives (at the federal and state level) for the purchase of ethanol powered automobiles;
- Credit subsidies for the purchases of ethanol powered automobiles;
- Differentiated rates for the highways maintenance tax (TRU);
- Authorization for gas stations to open during weekends if providing ethanol fuel services exclusively.

On the supply side:

- **Subsidised lines of credit for investment in crops and industries;**
- **Annual crop plans set by Governmental agencies, setting quotas for ethanol and sugar in each production unit in the country;**
- **Definition of a price parity between sugar-cane, ethanol and sugar;**
- **Purchase guarantees.**

Results: Ethanol was firmly introduced in the Brazilian energy matrix.

These policies caused a significant growth of investments in the construction or modernisation of more than 200 sugar mills, as well as an increase in the production of low moisture, or anhydrous, ethanol and, during its initial years, the programme was aimed at encouraging the addition of anhydrous alcohol to gasoline to replace imported tetraethyl lead. From 1975 to 1979, ethanol production grew from 580,000 to 3.676 million m³, surpassing its target by 15 per cent (BNDES and CGEE 2008). However, this increase was not sufficient to compensate for the rise in the import costs of oil derivatives, especially following a new international price shock in 1979.

In response to the new shock, the government expanded Proálcool, now tasked with the large-scale production of ethanol for use as the exclusive fuel for automobiles in the country. A set of measures was adopted to encourage the consumption of ethanol and, at the same time, guarantee a stable base for its supply.

The main consumption incentives were the reduction of taxes on the purchase and sale of ethanol-powered automobiles, the establishment of a price limit on ethanol at 59 per cent of the price of gasoline and the compulsory blending of 22 per cent of ethanol in gasoline. At the same time, the government pushed and subsidised auto companies to develop engines capable of running on ethanol alone (Meyer et al. 2012). In addition, the state-owned oil company Petrobras built a distribution and pump infrastructure for pure, as opposed to blended, ethanol (Meyer et al. 2012).

In response to these measures, the sale of automobiles fully powered by ethanol grew significantly in the 1980s, representing around 80 per cent of the total automobiles sold between 1983 and 1988. On the production side, the government encouraged the expansion of autonomous distilleries, designed for exclusive ethanol production, as a form of assuring the sustained supply of ethanol. Moreover, the financing programmes managed by the Brazilian Development Bank (BNDES) fostered the production of machines and equipment used in the harvesting of sugarcane as well as in the industrial phase of ethanol production, with the aim of substituting for imported capital goods.

Backed by BNDES' long-term loans at low or negative real interest rates, Brazilian-owned companies traditionally operating in the capital goods sector diversified their portfolios, heavily investing in ethanol-producing equipment. At the same time, new companies were established targeting specifically the production of capital goods used in ethanol production.

According to Pereira (2015), until the early 1990s, "the sugarcane agro-industry was one of the sectors in which state intervention was most intense. Official credit resources covered more than 80 per cent of the fixed investment in distilleries and the production of sugarcane." During the initial years of the programme, the expansion of sugarcane production principally occurred through the extension of planted areas, including in regions previously occupied by other economic activities, such as coffee cultivation or livestock raising.

The existence of Proálcool was contested despite the fact that Brazil was living under an authoritarian political regime for much of that period. Defenders of the programme pointed to its success in reducing dependence on oil imports, its principal objective. Critics pointed to the high cost of the programme, especially the amount of subsidies and its environmental and social impacts that involved both the expansion of the agricultural land area used for sugarcane and the pollution created by industrial ethanol production.

Despite its success in triggering the growth of ethanol production, Proálcool was weakened by a set of events that began in 1985. On one side, crude oil prices began to fall, while domestic production of oil was growing. At the same time, sugar prices increased, raising ethanol production's opportunity costs (Moreira 2008). On the other side, the new civilian government, elected in 1985, revisited incentive and subsidy policies to ethanol resulting in the reduction of average sugarcane agro-industry returns and stimulating even more switching of the raw sugarcane to sugar exports (BNDES and CGEE 2008). Facing growing inflation rates, the government reduced ethanol price guarantees below the cost of production. In 1986, ethanol output fell for the first time since the programme began (Meyer et al. 2012).

2.3. FROM GOVERNMENT INTERVENTIONISM TO DEREGULATION AND LIBERALIZATION

From the second half of the 1980s, the worsening of the macro-economic situation, and the exhaustion of the government's fiscal capacity, led to important changes in governmental ethanol policy and to reduced intervention in the sector.

By the end of the 1980s the ethanol sector had experienced a supply crisis that affected the domestic market through shortages, even forcing Brazil to import ethanol to fuel all its ethanol-only cars, and undermined the confidence of producers and consumers in Proálcool (Box 13.2).

As a result of this first Proálcool crisis, the sale of ethanol-powered cars fell sharply in just two years: in 1988, the share of these vehicles in total automobile sales in Brazil was 88 per cent. Two years later, this share had fallen to 12 per cent. Between 1995 and 2001, the market share of ethanol-powered cars in new sales was close to zero. Domestic ethanol supply stagnated and imports grew to meet the demand created by the first life cycle of the ethanol policy (Meyer et al. 2012).

Box 13.2: Deregulation and liberalization in the 1990s

Context: During this period, there was a fall in international oil prices, an increase in the domestic production of oil and a rise in the international prices of sugar. Brazilian Government implemented an encompassing set of modernizing structural economic reforms.

Main policy instruments:

- Dismantling of IAA;
- Phase-out of tax and credit incentives both to production and to the purchase of ethanol powered cars;
- End of price administration;
- End of the State monopoly in the production and exploration of oil.

Results: Dramatic fall in the market-share of ethanol-powered automobiles combined with an ethanol supply crisis. Market incentives to increase productivity and decrease production costs across the entire production chain.

This worsening of the macro-economic situation after the second half of the 1980s, expressed in skyrocketing inflation rates, and the policy shift implemented in the early 1990s, towards market liberalisation and deregulation, strongly affected ethanol production. At the institutional level, many that had been established to regulate markets and to control the supply of exports and substitution of imports were dismantled. In 1990, the IAA itself—symbol of government stewardship of the sugar and ethanol sectors—ceased to operate. During that decade, various measures further liberalised the market and prices in the sugar sector (Meyer et al. 2012).

Deregulation and market liberalisation led to the 1999 dismantling of the subsidy mechanism that kept gasoline prices above ethanol prices at a fixed margin. In the early phase of the ethanol policy, funds were transferred, through Petrobras with the monopoly on ethanol and gasoline distribution, from gasoline consumers to ethanol producers through pricing. This intrasectorial subsidy ended with price deregulation, though the government continued to support ethanol by taxing it favourably relative to gasoline.

From 1985 until 2003, annual ethanol production stayed within the 10 to 15 billion litres range. However, loss of subsidies motivated the industry to consolidate and increase production efficiency during this period (Goldemberg 2009). Productivity doubled—from 3,000 to 6,000 litres per hectare—while production costs declined significantly as focus on efficiencies worked along the entire value chain, moving from research on yield increases to adopting economies of scale through ever-larger distilleries. The search for pragmatic solutions led to the utilisation of bagasse, the stalks and pulp residue of the canes, to generate electricity (Meyer et al. 2012).

Hence, despite the fact that the 1990s are identified as a period of crisis for sugar and ethanol, the decade was also a period of intense institutional change affecting the sectors' complete shared and separate production chain. Besides institutional shifts within the federal government bodies associated with market deregulation and liberalisation, the sectors' business organizations and representation structures were profoundly transformed, with the emergence of new entities linked to the most modernised and productive areas of the sugarcane industry (BNDES and CGEE 2008). These were based in the São Paulo region and defended interests that, at times, were opposed to those of the more traditional areas, mainly located in the poorest Northeast region of the country (Pereira 2015). Broadly, the entities representing the São Paulo region preferred an end to government regulation and market liberalisation measures. By contrast, the Northeast interests asked for price regulation and other measures of market control.

It was also in the 1990s that ethanol policy and the environment agendas intersected for the first time when the environmental aspect began to gain relevance in the Brazilian public policy debate. To a certain extent, this resulted from the 1992 Rio Conference that Brazil hosted and the commitments it made there. In 1993 the Federal Ministry of the Environment was created and the more developed States, such as São Paulo, at the time the largest ethanol producer, adopted environmental legislation that directly effected the sugar and ethanol sectors and that encouraged the mechanisation of harvesting.[29]

3. THE SECOND PHASE OF THE ETHANOL POLICY: 2002 TO 2015

3.1. ETHANOL IN TIMES OF CLIMATE CONCERN

The sugar and ethanol sectors only began to recover from the long crisis of the 1990s in 2002. However, the recovery could not count on the incentives and subsidies characterizing the first policy cycle. In the second cycle, the stimulus came from demands of the international market and from the main industrial sector that consumed ethanol, automobiles, and any associated government incentives.

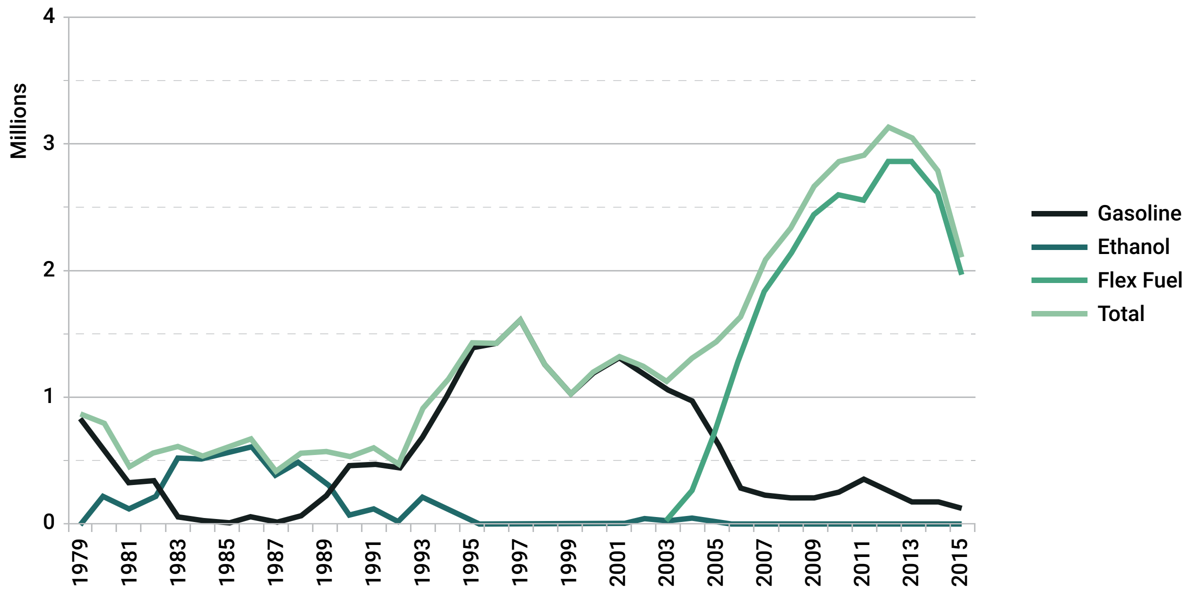
Two factors explained this recovery. One is that various countries decided to replace their consumption of fossil fuels with the use of products from renewable energy sources, in particular, biofuels such as ethanol. The other factor is a technological innovation, the launch of flex-fuel automobiles that can be powered by gasoline or ethanol or by combinations of the two (Moreira 2008).

The technological game changer at the domestic level, directly affecting the most relevant demand for Brazilian ethanol, was the introduction and diffusion of the flex-fuel engine, developed by Bosch, a multinational present in Brazil. In 1994 Bosch recognised the potential for engines that could replace the ethanol-only version that was declining in popularity. This engine operates with gasoline or ethanol, or with a mix of the two fuels. It was well received by Brazilian consumers, completely replacing engines operated only with ethanol. Brazilian consumers appreciated a car that would not become obsolete as fuel prices, and government policies, fluctuated. This attraction was matched by the promise that the country's wide-ranging infrastructure would adapt and that consumers would have increased security through the availability of gasoline, ethanol, or any mixture of the two. It would also represent savings for car manufacturers, as they would no longer have to supply duplicate models to meet demand for alcohol and gasoline powered vehicles. For producers, it would allow greater flexibility to offer their product to either the ethanol or sugar end use according to which opportunity is more advantageous at the time (Szwarc 2002).

29 The State of São Paulo prohibited the burning of the sugarcane before its harvest and set a timetable for the adoption by the producers of the mechanical harvesting.

In 2004, around half of the automobiles sold in Brazil had flex-fuel engines, a share which reached 90 per cent in 2007 (Figure 13.1). That year, sugarcane became the second most important source of energy in the Brazilian energy matrix, after oil. From 2007, only cars powered by gasoline and flex-fuel cars were manufactured. By 2012, half the Brazilian fleet was already flex-fuel (Pereira 2015).

Figure 13.1: Number of licensed vehicles per type of fuel, 1979–2015



Source: Adapted from UNICADATA (n.d.-a).

The political game changer between the first and second policy cycles was the growing international perception of climate risks and the enormous responsibility of fossil fuel burning for the greenhouse gas emissions that cause global warming. Some consider the signing of the Kyoto Protocol in 1997 as the first effective and coordinated move to confront the problem at the global level. For the first time, developed countries assumed commitments to reduce emissions. Although these commitments were non-binding, they led several countries to adopt measures encouraging the use of biofuels in the transport sector. Ethanol, especially from sugarcane, was identified as one of the most promising options to replace fossil fuels (Box 13.3).

Box 13.3: The energy and environmental balance of sugarcane ethanol

Sugarcane ethanol is recognised as a product with very positive environmental and energy attributes, even in comparison with other biofuels. The energy balance of ethanol registers an average energy output/input of around 8.3, against less than 2.0 for the main biofuel alternatives of corn, sugar beet, wheat straw and timber. All the energy necessary for the production of ethanol comes from the bagasse or residue of the cane. The direct consumption of fossil fuels in the production process is limited to transport trucks, agricultural machinery, and fertilisers. Moreover, since sugarcane ethanol production costs are lower than those of other biofuels, the net energy return on investments for ethanol from sugarcane is much higher than competing biofuels. Due to these characteristics, greenhouse gas emissions from the production and consumption of ethanol are much lower compared not only to gasoline but also to other biofuels. In 2004, the ethanol sector avoided emissions equivalent to 13 per cent of the total greenhouse gases emitted by the industrial and commercial sectors in Brazil. More recent data indicates that, combined with the required mixture of 25 per cent of biofuels in gasoline, the consumption of ethanol by flex-fuel vehicles allowed reductions in greenhouse gas emissions exceeding 40 million tons of CO_2 equivalent annually. Assad et al. (2012) show that in a scenario of production expansion, the GHG emission reductions obtained through the use of ethanol in 2020 would be sufficient to reach and even surpass Brazil's targets stipulated in the National Climate Change Policy for the transport sector.

An assessment of the ethanol life cycle considered its environmental impacts on air, water, soil, the use of land including competition with food production, and biodiversity. Also included in the assessment were social aspects, such as impacts on employment, wages, income distribution and landholding structure, as well as working conditions. The balance of the assessment is very positive, although it does recognise problems and challenges in some areas, especially in relation to working conditions. The assessment of ethanol presented by Koizumi (2014) also registered the highly favourable energy and environmental balance of ethanol, as well as the benefits of its production on work and economic variables, such as oil imports.

Nevertheless, ethanol development policies in Brazil have been questioned by critics in relation to their direct and indirect impact on the use of land, and more specifically about the production of food and Amazonia deforestation. According to various evaluations, this questioning found scarce support in reality, since the direct impact of the expansion of the area occupied by sugarcane was on degraded pasture, while its indirect impacts only contributed marginally to deforestation. However, there are less optimistic assessments, especially in relation to the indirect impacts of the expansion of sugarcane: For example, De Sá et al. (2013) did find evidence of a positive relationship between cattle ranching in Amazonia and sugarcane expansion in the south of the country. The effect is that sugarcane production moving into degraded pasture pushes ranches into the Amazonia forest frontier, materialised dynamically over 10 to 15 years periods.

Source: Farina et al. 2013; Goldemberg et al. 2008; Koizumi 2014; Walter et al. 2008.

When the international context shifted more towards environmental concerns, Brazil had vast industrial and agricultural installed capacity for the production of ethanol and a wide infrastructure for distribution and sale of the product all over the country. However, it was still recovering from the crisis that marked the end of the first life cycle of its ethanol policy. As well, it is worth noting that the introduction of the flex-fuel engine as an option for consumers by automobile producers in Brazil, all multinationals, was not directly linked to any governmental incentive programme.

The introduction of a new tax, levied on the import and sale of fuels, helped diffuse this flex-fuel innovation. Contribuição de Intervenção no Domínio Econômico–Combustíveis (CIDE–Fuel) is a tax that falls on contractual obligations implying the transfer of technology: the payment of royalties. Although the import and the sale of fuels do not fit into the activities under the scope of the CIDE tax, the Brazilian government used this instrument to regulate the relative prices of fuels that compete with each other, especially gasoline versus ethanol. According to the law creating the tax, the funds raised were to be used in environmental programmes to reduce the effects of pollution caused by the use of these fuels or to improve the transport infrastructure (Box 13.4).

Box 13.4: Flex-fuel automobiles and international commodity prices from 2003 to 2008

Context: During this period, the main drivers were: (i) in the domestic context, the launching of flex-fuel automobiles; (ii) in the international arena, the decision of many relevant economies to increase the share of renewables (and biofuels, in particular) in their energy matrix and the rise in the oil prices after 2004–2005.

Main policy instruments:

On the demand side:

- Tax incentive on the purchase of flex-fuel automobiles;
- Introduction of CIDE fuel in 2001—a typical regulatory tax on the sales and imports of fuels, with rates over fossil fuel representing, in the beginning, more than twenty times the level incurred on ethanol.

On the supply side:

- Increase the public financing (BNDES) for long term investment in new plants.

The taxation level was fixed, in the case of gasoline, at a value equivalent to more than twenty times the value of the tax rate imposed on ethanol, so it had a huge impact on the relative price of the two products. Moreover, the reduction of the tax on industrialised products or on the sale of automobiles powered by ethanol or with a flex-fuel motor was extended. The increase in oil prices after 2004 was another incentive to spread flex-fuel models and the use of ethanol as a fuel for the Brazilian automobile fleet.

After 2003, propelled by strong growth in demand, ethanol production went through a period of consolidation, marked by a concentration in large companies, and by the entrance into the sector of business groups from the food and energy sectors (Nastari 2012). An immediate consequence of this process was the modernisation of the management and the professionalisation of many companies, until then controlled by the families traditionally established in sugarcane production. In the expectation of strong growth in ethanol production, some large companies from the sector opened their capital and resorted to the capital market to fund their investments. In the international sphere, increasing oil prices renewed concerns about energy security. These added to concerns about climate change and defined a set of economic incentives to accelerate the shift to renewable energy.

Various developed countries adopted policies to increase the proportion of biofuels in their energy matrices, with the US being especially active in this process and overtaking Brazil as the largest global producer of ethanol in 2005. In response to these evolutions in the domestic and foreign spheres, the ethanol sector entered a new investment cycle, characterised by the expansion of sugarcane production through productive improvements and in areas already occupied by human activity, rather than exploiting frontiers or pristine landscapes (Nassar et al. 2008). Instead, production improvements resulted from replanting areas previously used for other crops, the establishment of new alcohol production mills, and the development of sub-products such as electric energy and alcohol-chemistry (Moreira 2008).

The nominal value of disbursements by BNDES multiplied fivefold between 2004 and 2007, in support of sugarcane production and the ethanol industry.[30] The area planted with sugarcane increased 65 per cent between 2003 and 2009, while ethanol production rose 87 per cent

30 Between 2001-02 and 2007-08, Brazilian production of ethanol grew at an annual rate of 10.2 per cent, due to modern production units established in the South East regions of the country.

between the harvests of 2003-04 and 2008-09, an increase completely attributable to the production of innovative hydrous ethanol, which expanded by more than 210 per cent in this period (UNICA-DATA n.d.-b).

As external demand for the product grew, Brazilian ethanol exports to developed countries, principally the European Union, expanded considerably. Between 2003 and 2008, exports increased by about 650 per cent. Scenarios on the issue, such as an OECD and FAO (2007) projection to 2016 as its time horizon, predicted a promising future for global ethanol consumption, as well as brilliant prospects for Brazilian ethanol exports. According to those optimistic projections, Brazil would have been responsible for 85 per cent of global ethanol exports by 2017.

Dating from this period are the first attempts in Brazil, in cooperation with the US, to define an agenda to transform ethanol into an international commodity, a precondition for the consolidation of a global market for the product. The 2007 Brazil–USA Memorandum of Understanding allowed for cooperation between the two countries to establish technical norms and standards for ethanol, while at the same time stimulating production and exports from other countries, notably in Central America and the Caribbean (ICTSD 2007).

Nevertheless, in this period of growth in production, domestic consumption and exports, Brazilian ethanol was criticised, especially in European Union countries, by arguments based on criteria of social and environmental sustainability. Thus biofuels, that had been seen as one of the solutions to mitigate the effects of global warming in the 1990s, were blamed in the 2000s–in scientific articles, organizations and forums, and by the media–for causing deforestation, increasing food prices, and even threatening global food security (Moreira 2008). The Brazilian ethanol industry saw this critique as a manifestation of agricultural protectionism from European countries. According to the producers' perception, it ignored the superiority, in terms of social and environmental performance, of Brazilian ethanol in relation to other biofuels and the possibility of the expansion of sugarcane production in Brazil without generating any deforestation of tropical forests or compromising food products. At the same time, the international critique echoed with Brazilian stakeholders, such as environmental NGOs and those concerned with social and labour aspects. These denounced the labour conditions found in sugarcane production, the conflicts between expanding large landholders and peasants, the environmental pollution generated by the production of sugarcane and ethanol, and the destruction of native vegetation (Duarte et al. 2013).

However, the institutional reaction of the sector was not limited to refuting this critique on the basis of technical arguments. Indeed, the Brazilian Sugarcane Industry Association (UNICA) opened an office in Brussels and increasingly became involved in international discussions on the socio-environmental certification of products in the ethanol production chain (Chiodi et al. 2014).

3.2. THE SECOND ETHANOL POLICY CRISIS

The international economic crisis that was triggered in 2008 reversed the positive trends in Brazilian ethanol exports and investments in the sector. Exports had a significant recovery in 2011 and 2012. However, this export performance did not reflect the dynamism of the sector, but instead showed the weakness of domestic demand, largely due to changes in policies applied to fossil fuel prices. Since 2006, consumer prices of oil derivatives no longer varied periodically and, with the exception of 2013, all price increases incurring at the refinery phase were offset by the reduction of federal taxes imposed on the product, to keep the gasoline pump prices stable and avoid economic inflation. The compensatory mechanism used to prevent increases in consumer gasoline prices was the CIDE-Fuels tax (Farina et al. 2013), with values gradually reduced during the period and reaching zero in July 2012. During this post 2008 financial crisis phase, the production of sugarcane and ethanol also suffered from unfavourable climatic conditions, as droughts affecting three successive harvests.

As a result of these policy shifts, between January 2006 and December 2012 the average price of gasoline for Brazilian consumers increased by 10.5 per cent in nominal terms, in contrast with an accumulated inflation rate during the same period of 42.1 per cent, which implied a fall in the price, in real terms, of 22.2 per cent. On the other hand, between June 2006 and December 2012 the consumer price of ethanol rose by 56.3 per cent in nominal terms, and a little more than 10 per cent in real terms, according to Agência Nacional do Petróleo, Gás Natural e Biocombustíveis, the governmental agency in charge of regulating the activities in the field of oil and gas (ANP 2016).

As noted by Farina et al. (2013), the spread of vehicles with flex-fuel engines allowed the consumer to decide the type of fuel to be used at the moment of filling the tank at the pump, thereby increasing consumers' sensitivity to the relative prices of ethanol and gasoline. Traditionally, drivers choose ethanol to fill their tanks when it cost less than 70 per cent of the value of gasoline, since the fuel extracted from sugarcane produces around 30 per cent less energy per liter, compared to gasoline. Hence, the sensitivity of the consumers to government policies affecting the relative prices of gasoline and ethanol grew substantially as more, and then most, people drove flex-fuel autos.

The domestic fuel price policy generated many negative effects for the ethanol production sector. These effects materialised at a moment when the impacts of the international crisis had hurt a significant part of the sector and produced a sharp retraction in external demand for ethanol. Paradoxically, the policy and its effects materialised during a period when the international prices of oil rose significantly (Box 13.5) (Kutas 2015a).

Box 13.5: Back to the crisis: since 2008

Context: The discovery of huge offshore oil deposits and the expectations created around the economic development effects of their exploitation led to a downgrade of the ethanol position in the ranking of the Brazilian energy policy priorities. Besides, the international economic crisis had severe repercussions on the financial/corporate structure of the firms operating in the sector.

Main policy instruments:

On the demand side:

- Use of CIDE-Fuel as a compensatory mechanism to prevent inflation, reducing its rates to zero in 2012;
- Gasoline price administration to reduce its impacts on inflation;
- New set of heavy incentives to the automotive industry as part of the new industrial policy;
- Gradual increase in the share of ethanol in mixed gasoline, reaching 27 per cent in March, 2015;
- From 2015 onwards, in the mid of a fiscal crisis, Brazilian central government and some of the states, as well, began to increase taxes (CIDE, PIS/COFINS, ICMS) on gasoline.

On the supply side:

- BNDES introduced new lines that finance the stocking of ethanol and a support programme for the renovation and expansion of sugarcane plantations aimed at increasing their productivity.

Results: Closing of 14 per cent of sugarcane processing mills, growth of only 3 per cent in the production of ethanol, while planted area rose 23 per cent, with a significant productivity decrease in the period 2008–2009 to 2014–2015. Despite the launch of new financing lines by BNDES, the amount of credits for the sector fell to their lowest level in almost ten years.

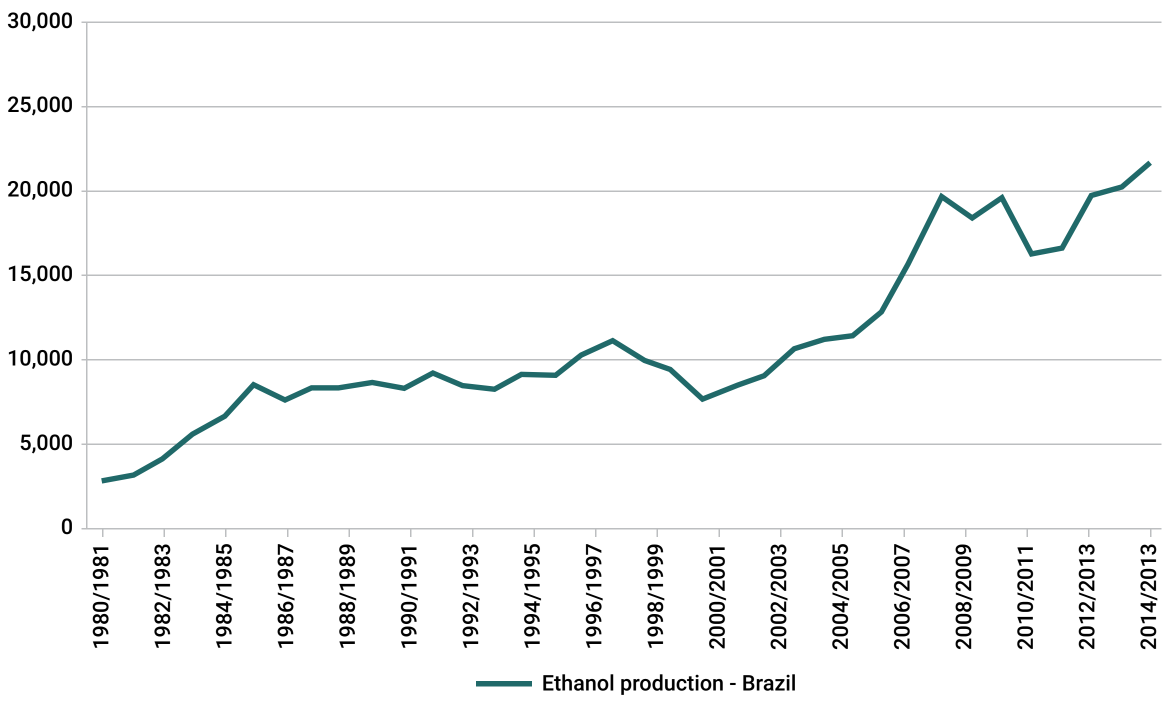
In response to the slowdown of the economy from 2011 onwards, the government adopted a series of measures aimed at stimulating industrial production and investments, giving special emphasis to the automobile sector. The automobile fleet grew significantly, around 42 per cent between 2008 and 2013, but the proportion of ethanol in the energy matrix fell considerably, reaching 33 per cent in 2012. The fall is even more significant for light vehicles: in 2012 only 17 per cent of the total energy consumed by them were ethanol (Farina et al. 2013). In turn, the volume of hydrous ethanol produced fell from 19 billion litres in 2010–11 to 12.7 billion litres in 2013–14 (UNICADATA n.d.-b).

Ethanol's waning focus for governmental policies is also due to immense offshore oil deposits that Petrobras discovered of Southeast Brazil in 2006. The government presented the discovery as the beginning of a new economic and social development phase for Brazil. It also inspired a new cycle of policies aimed at the import substitution of goods and services, now in the oil and gas sector. A vast political and business coalition was established around the aim of exploring the recently discovered oil deposits and sharing the royalties and profits deriving from them.

In this scenario, it was not a surprise that the environmental implications of the policies giving a high priority to fossil fuels were not part of the debate. Against this background, ethanol policies lost relevance in the public policy agenda. In contrast, during the same period, wind energy gained attention in Brazil, with the support of public financing administered by BNDES. The government held the first wind energy bid in the country in 2009 and, to encourage domestic production of wind energy generation equipment, it raised the import tax for wind turbines from zero to 14 per cent, though the tariff remained at zero for equipment with a superior generation capacity (Oliveira 2012). In ten years, wind energy generation rose from 27.1 megawatts to 8.7 thousand megawatts of installed capacity, equivalent to 6.2 per cent of the Brazilian electrical matrix (Pereira 2016). The fact that the government had identified a relevant potential for the import substitution of machinery and equipment helps to explain the focus placed on wind energy by public policies aimed at stimulating investment and local production.

The effects of these developments on the ethanol industry were significant. Between the 2008-09 and 2014–15 harvests, production of ethanol grew only 3 per cent in contrast to the 87 per cent between 2003-04 and 2008-09. The area planted with sugarcane rose by 23 per cent in this period in contrast to 65 per cent, between 2003-04 and 2008-09 (Figure 13.2) (UNICADATA n.d.-c).

Figure 13.2: Ethanol production in Brazil, 1980–2015 (Thousand m³)



Source: Adapted from UNICADATA (n.d.-b).

Investments in the complete production chains for sugarcane and ethanol were also affected. In 2015, BNDES credits for the production chain fell to their lowest level in almost ten years. Repercussions were felt on investments for the planting and renovation of sugarcane plantations, as well as on industrial expansion projects and the construction of new units, which continued to fall in 2015. Furthermore, this occurred despite BNDES having introduced new lines of financing dedicated to the sugar and ethanol production sector in 2010. These included a programme for financing the storage of ethanol and a support programme for the renovation and expansion of sugarcane plantations, since their productivity had been falling.

Again, a side effect of the crisis has been a new cycle of corporate restructuring and consolidation. On the one hand, about one third of the companies in the sector faced difficulties as many mills were in debt and operating at a loss (Duarte et al. 2013). From 2008 onwards, nearly 15 per cent of the sugarcane processing mills closed and many others faced financial difficulties and high debt

(Kutas 2015b). In January 2016, there were 85 mills under judicial bankruptcy protection and many others negotiating with creditors to restructure their debts (Batista 2016). On the other hand, investors with a background in agro-industry, oil, and chemicals entered the sugar and energy sector, bringing in new entrepreneurial expertise. This led an analyst of the sector to estimate that in the first half of 2011, more than 70 per cent of the sector had good assets, capital structures and governance, operational performance and access to high quality capital (Jank 2011).

Another positive development, from a strategic point of view, is that the ethanol producers adopted an agenda for dealing with new challenges, including the concept of social/environmental certification. This initiative is part of the sector's reaction to the increased questioning by some developed countries on the effects of sugarcane production on deforestation, food security and working conditions, among other concerns (Chiodi et al. 2014).

A study done by UNICA, carried out in 2011, stated (UNICA 2012):

> "the Better Sugarcane Initiative (Bonsucro), a global certification launched in July 2011, which assessed the sustainability of products manufactured from sugarcane, is currently the model of certification most used in Brazil covering 20 sugar energy companies and more than 437,000 hectares of sugarcane, equivalent to more than 1.7 per cent of the sugarcane planted in the world".

Bonsucro certification system includes two standards (Bonsucro product standard and Bonsucro mass balance chain of custody standard) and a certification protocol. The certificate holder is the mill, which holds the ultimate responsibility for compliance. The Bonsucro product standard contemplates six principles referring to respect to the laws, human rights and labour standards, management of input, production and processing efficiencies to enhance sustainability. Each principle has its own criteria, indicators and standards defined for the different phases of production (agricultural and industrial). In 2016, 124 out of the 400 members of Bonsucro are Brazilian companies, including producers of sugar and ethanol (the large majority), multinationals operating in the country in sectors supplying raw materials and machinery for the production of sugar and ethanol, and associations of sugarcane suppliers to the processing industries of the sector.

In more recent years, the federal government adopted measures favourable to ethanol, such as the increase in 2013 of the share of ethanol in gasoline from 20 per cent to 25 per cent. In March 2015, the percentage was increased again, reaching 27 per cent in the case of common gasoline. Also in 2015, some Brazilian States increased taxes on fossil fuels or reduced those on ethanol while the federal government raised the value of CIDE-Fuel and federal taxes on gasoline and diesel. The sugar-producing sector pressed for a new and significant increase of CIDE for gasoline, but did not obtain this decision from the federal government. Even more important, from 2015 onwards, the federal government began to distance itself from its gasoline price management policy, and consumer gasoline prices increased substantially. In January, as a consequence, the average price of gasoline for consumers was 21.2 per cent higher than one year earlier. This set of recent policy measures led to increased consumption of ethanol in Brazil, but did not foster a new cycle of investment. Investments in capacity expansion in the ethanol sector have been frozen since 2008.

3.3. THE PAISS PROGRAMME: PUSHING TECHNOLOGICAL INNOVATION

At the same time, there has been significant public investment aimed at fostering fundamental green innovation in the industrial sectors of the sugarcane production chain. In 2011, BNDES and the public agency responsible for financing innovation projects, FINEP, joined efforts to launch what became 'PAISS Industry', a programme supporting technological innovation in the sugarcane and ethanol industries. The resources formally allocated by both institutions to the programme for the period 2011–2014 amounted to 600 million.

The objectives of the programme were to support the development of second-generation bioethanol that exploits sugars converted from cellulosic materials; to develop high-biomass sugarcane, energy cane; and to foster new gasification technologies required for treating sugarcane biomass (CGEE 2016).

According to Milanez et al. (2015), ethanol productivity could increase up to 50 per cent with the new technologies. CGEE (2016) concludes, "The perspective to improve the potential yield of bioethanol to almost 25,000 litres per hectare is real." As a consequence, global CO_2 emissions and pressure on land and food prices could be significantly reduced (Nyko et al. 2010). CGEE

(2016) estimates that ethanol from energy cane alone could replace 10 per cent of the total gasoline consumed globally on less than 10 million hectares of land.

The policy instruments used by PAISS were financial: credit, equity, non-reimbursable support for cooperation projects between private companies and centers of research, and economic subventions. It was operationalised through a call for projects to be presented by the companies, which were then selected on their merits. In February 2014, BNDES announced that this PAISS Industry programme had disbursed the amount of US$ 1 billion to support 35 innovation projects in 57 companies, with a total investment that should reach US$ 1.4 billion. The production of cellulosic ethanol for 2015 in Brazil was estimated at 140 million litres (Milanez et al. 2015).

In 2014, a new phase of the PAISS programme began, with the launching of 'PAISS Agriculture' that targets innovation and development of new technologies in the agricultural sectors and activities of the production chain. At its launching, the new initiative was allocated around US$ 620 million in public resources available for the same financing modalities that were operationalised through PAISS Industry.

The main focus of PAISS Agriculture is innovation in areas directly relating to genetic improvements and the enhancement of productivity of sugarcane in Brazil. However, it also targets industrial segments producing machines and equipment for agriculture, emphasizing innovation geared at fostering the use and diffusion of precision agriculture techniques. In 2014, 35 business plans had been approved with the framework of PAISS Agriculture, totalling US$ 849 million for the period from 2014 to 2018.

Although it is certainly too early to assess the success of the PAISS Programme, some initial assessments of the design and implementation have been published (Milanez et al. 2015; Bomtempo 2014). In broad terms, these assessments highlight the main positive elements of the PAISS Programme as:

- The high level of coordination between BNDES and FINEP, the public agencies responsible for the implementation of the programme, allowing for synergies between different instruments and modalities of financial support
- The building and operation of three second generation ethanol plants, with two at commercial scale, and taking the projects beyond lab or pre-operational levels
- The incentives for cooperation schemes between companies and between companies and research centers, through specific mechanisms of financing and/or non-reimbursable funding.

As to the weaknesses of the programme, Milanez at al. (2015) criticise that the incentives target expansion of supply only, in contrast to policies that also cover demand-side incentives. According to Bomtempo (2014), other problematic aspects of the programme include poorly defined criteria to select the projects and the absence of mechanisms to effectively monitor implementation of the projects, as well as instruments that condition the continuation of government support on performance.

Though these programmes are significant in fostering green innovation in Brazilian ethanol, Brazil was a latecomer in the development of second-generation ethanol (Nyko et al. 2010). According to Kutas (2015b), this can be attributed to the lack of pressure to go beyond the first generation because of land availability, no need to trade off between food production and biofuels and the good environmental and climatic performance of first generation ethanol.

4. POLICY LESSONS

Due to the long history of ethanol policies, Brazil now has one of the most successful programmes in the world for the use of renewable energy in the transport sector. No other country in the world has a fleet of almost 20 million light vehicles that can use any combination of gasoline and sugarcane ethanol the consumer wants to use (Farina et al. 2013). Despite recent difficulties, Brazil has maintained its position as the second largest producer of ethanol in the world, accounting for 25 per cent of global production and 20 per cent of global exports. In 2014, sugarcane was the second principal source in the Brazilian energy matrix, with 15.7 per cent of the total, compared to 39.4 per cent for oil and gas (Kutas 2015b).

As described in the previous sections, a wide set of policy instruments, including investments, price subsidies, and demand incentives, were deployed in the 1980s to promote suppliers in the agricultural and industrial sector, especially in sectors producing capital goods such as agricultural machinery and equipment for sugarcane processing, ethanol production and stocking

While, in the last decades, the producers of agricultural machinery have benefited from the strong performance of the Brazilian agricultural sector as a whole–and particularly from the commodities boom of the past decade–companies engaged in the production of industrial capital goods for ethanol mills suffered from the ups and downs of ethanol production and of the associated policies. As a consequence, industrial spillovers arising from ethanol policies to supply sectors, although relevant, were limited by the volatility of the demand that the ethanol-producing firms had for dedicated capital goods.

In principle, the pattern of government intervention applied to the ethanol sector and the instruments mobilised to foster its emergence do not differ from the ones that guided the import-substitution industrialisation that Brazil went through in the previous decades: High tax and credit subsidies combined with instruments and incentives adapted to the specific features of the sector. The direct and indirect subsidies mobilised by the ethanol policies have been substantial compared to the size of the Brazilian economy, but were significantly reduced at the end of the 1980s, forcing the industry to consolidate (Meyer et al. 2012).

There is no doubt that the ability to foster the emergence of new producers in the Southeast, the most developed region of Brazil, and to attract investors and large companies from other activities to the ethanol industry has been one of the main successes of the ethanol policies. This was essential for the technological and organizational modernisation of the firms acting in the sector and ultimately for their survival despite the ups and downs in its performance and the swings in the public policies. It created the conditions for reducing the production cost of ethanol, which decreased by 65 per cent from 1976 to 2005 for a number of reasons, including innovation in research and development, economies of scale and the effects of learning by doing (Meyer et al. 2012). The crisis that the ethanol sectors underwent from 2008 was largely due to a combination of policies geared at controlling the consumer prices for gasoline in the domestic market, in a period of high international oil prices, with the reduction of the value of CIDE-Fuels incurred on gasoline sales, reaching zero in July 2012.

The assessment of ethanol industrial policies in Brazil should consider the nature and specific characteristics of this industry, at the supply as well as at the demand level. From the point of view of its final use, ethanol competes with fossil fuel and the demand for it depends basically on the relative prices of the two products, besides the regulation related to the gasoline mix with ethanol.

Industrial policies aimed at fostering the demand for ethanol in Brazil combined incentives for the development of ethanol-powered cars and later for flex-fuel cars. Associated price controls or use of a specific tax, CIDE-Fuels, kept relative prices of ethanol attractive to consumers. The launching of flex-fuel cars, stimulated by tax and credit subsidies, created a potentially large and growing market for ethanol and helped to increase the price elasticity of the demand for ethanol in Brazil (Farina et al. 2013). Consumption of ethanol depended strongly on the price of gasoline.

An additional factor that played a relevant, although secondary, role in stimulating ethanol production is the external demand. Although industrial policies can do little to increase foreign demand, trade policies can help. Brazil engaged in trade negotiations with developed countries in the mid-1990s at the Doha Round and other venues, with the liberalisation of trade barriers to ethanol as one of its top priorities in terms of market access demands. Furthermore, the country signed a memorandum with the US to define an agenda for disseminating the use of ethanol around the world, through the establishment of technical standards. None of these initiatives resulted in relevant achievements and ethanol exports still face relevant barriers to enter foreign markets.

On the supply side, ethanol competes with sugar for sugarcane as a raw material. Furthermore, being an agricultural commodity, sugarcane production and productivity depend on climate instabilities, soil conditions and other variables. While processing facilities exist that produce ethanol exclusively, the large majority of producers process the sugarcane to produce sugar and ethanol, in a mix that depends on relative prices of both products. Therefore, while on the demand side the incentives to produce ethanol depend strongly on the domestic policies related to fossil fuels, on the supply side these incentives are strictly conditioned by the relative prices of ethanol and sugar, and so by the fluctuations and trends in the international prices of sugar. These specific features of ethanol production tend to create a structural volatility in its supply, leaving it vulnerable to the vagaries of policies and markets for sugar and for fossil fuels. With new research on energy cane varieties geared specifically for ethanol production, this linkage between ethanol and sugar may be broken in the future, thereby stabilising the ethanol market.

Ethanol industrial policies have to deal with these sector-specific characteristics if they aim to foster the development of the sector, with or without environmental motivations. During the period of strong government intervention, a wide set of policy instruments were used. As already stressed, the main instruments were subsidised credit lines for investment and production, price administration and arbitration between sugar and ethanol, and purchase guarantees. Except for BNDES' credit lines for investments, which can include a subsidies component, and the recent support for innovation in second-generation ethanol, most of these instruments have been phased out.

Actually, the subsidy component of the ethanol industrial policy has lost relevance. As more interventionist policies tend to be unfeasible for fiscal reasons, government policies are likely to concentrate on two instruments: the mandatory blending of gasoline and ethanol and using CIDE-Fuel to influence the price ratio in favour of ethanol consumption. Especially in a period of low international oil prices, these instruments seem to be best fitted to drive the performance of this industry in the next years, while at the same time avoiding the introduction of artificial distortions in the management of gasoline's domestic prices.

In recent years under the PAISS programme, Brazil has moved in a different direction, away from consumption mandates and demand-driving pricing schemes, toward supply-side interventions designed to boost the productivity of the agricultural resource. While there are encouraging signs, it is too early to tell whether this new approach ultimately will be successful. This is partly because we have too few years of data, and partly because the commercialisation of second-generation ethanol is still in its early stages. Success in such a dynamic field, so crowded with international competitors, is inherently uncertain.

5. CONCLUSIONS

Reference was made, in the introduction, to the ambivalence of the ethanol policies in Brazil, when assessed according to green criteria.

On one hand, these policies can be considered green, to the extent that, irrespective of their rationale and motivations, they actually promoted changes in the structure of the energy matrix, in a direction compatible with the objectives of sustainable development. Nowadays, more than 15 per cent of Brazil's energy matrix has sugarcane as its source and the balance of greenhouse gas emissions from the production and consumption of ethanol is clearly favourable compared to that of gasoline and other biofuels. Therefore, from the point of view of their aggregate result, industrial policies targeting the ethanol production, besides being successful as import substitution policies, can also be considered green.

When the entire life cycle of ethanol production is considered, the picture is more nuanced. Specifically, ethanol development policies in Brazil have been criticised for both their direct and their indirect consequences for land use, specifically their effect on food production and Amazonia deforestation. According to various evaluations, this critique is largely unfounded, since the direct impact of the expansion of the area occupied by sugarcane was on degraded pasture, while its indirect impacts only contributed marginally to deforestation. Other authors disagree with this view, pointing to the indirect impacts on the Amazon region of the expansion of sugarcane production. These discussions will continue, as sustainability becomes a mainstream concern (Box 13.3).

On the other hand–and this is the ambivalence–the implementation of ethanol policies reveals a narrow perception on the part of the government of their green dimension. This appears clearly in the first phases of Proálcool, during the military regime, when the expansion of sugarcane production did not consider the environmental effects and the social consequences. During the initial years of the Programme, the expansion of sugarcane production principally occurred through the extension of the planted areas, including in regions previously occupied by other economic activities, such as coffee or livestock raising (Oliveira 1982). In this period, the working conditions in the production and harvesting of sugarcane, activities that involved a large number of temporary workers due to the low level of mechanisation, were far from adequate even when assessed according to the Brazilian legislation.

But the narrow perception of the green dimension of the ethanol policies is also made explicit by a more recent episode: the shift in domestic policies that hurt the sector in the late 2000s. It is striking that the recent crisis in the ethanol sector, mostly driven by domestic policy choices related to the price of fossil fuels, followed a period when ethanol was praised in Brazil and in other countries for its green attributes. At this time, Brazil supported the use of ethanol as a biofuel, while pushing for the inclusion of ethanol in the list of environmental goods during the Doha Round negotiations at the WTO. It was impossible to imagine that a few years after this period of ethanol-euphoria the sector would go through a deep crisis that is still ongoing.

If ethanol policies in Brazil had been linked more explicitly to environmental objectives, the sector would have been a strong candidate for receiving continued support from the government. Government policies, however, generated a high level of uncertainty and unpredictability that has damaged the sector and its performance. The past changes of ethanol policies in Brazil indicate how vulnerable these can be with regard to economic cycles and government priorities that are not directly linked to environmental and climate goals. As a matter of fact, until the advent of the relatively recent PAISS programme, the green dimension has never played a major role in the design of ethanol development policies in Brazil. Conceived to promote ethanol as a substitute for fossil fuels during the oil crisis of the 1970s, these policies ended up linking the ventures of this sector to the volatility of the domestic policies for the fossil fuels sector. Thus, PAISS in this sense represents a distinct departure from previous policies.

Finally, the ethanol policies have been oriented only partly towards industrial upgrading and technological learning. The main policy focus was on increased agricultural productivity. Some technological spillovers, however, are worth mentioning. These include the development of innovative flex-fuel engines; processing of ethanol-based chemicals; and sophisticated sugar and ethanol processing plants, which are likely to receive a technological boost with the shift to processing cellulose-based ethanol.

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