Industry 4.0 and Productivity

UNIDO EQuIP Presentation
Pretoria, December 2019

Juergen Amann

Outline

- **Introduction**

  What do we mean by industry 4.0 and new technology?

- **Technology adoption**

  To what degree is a country integrated in the adoption of new technologies?

- **Robotization**

  Are jobs at risk of being replaced by new technology?

- **Runner industries**

  Will new technologies inevitably lead to 'jobless' growth?

Introduction

What do we mean by industry 4.0 and new technology?

Innovations and their consequences.

- 1956: Hard Drive
- 1958: Jet Airliner
- 1959: Integrated Circuit
- 1962: Communications Satellite
- 1968: Integrated Computer Systems
- 1970: Fiber Optics
- 1974: Barcode
- 1976: Supercomputer
- 1977: Personal Computer
- 1978: GPS
- 1983: Microsoft Word
- 1986: Electronic Mailing List
- 1989: World Wide Web
- …
- **Industry 4.0**
- …
- Future technologies

Innovation and their consequences

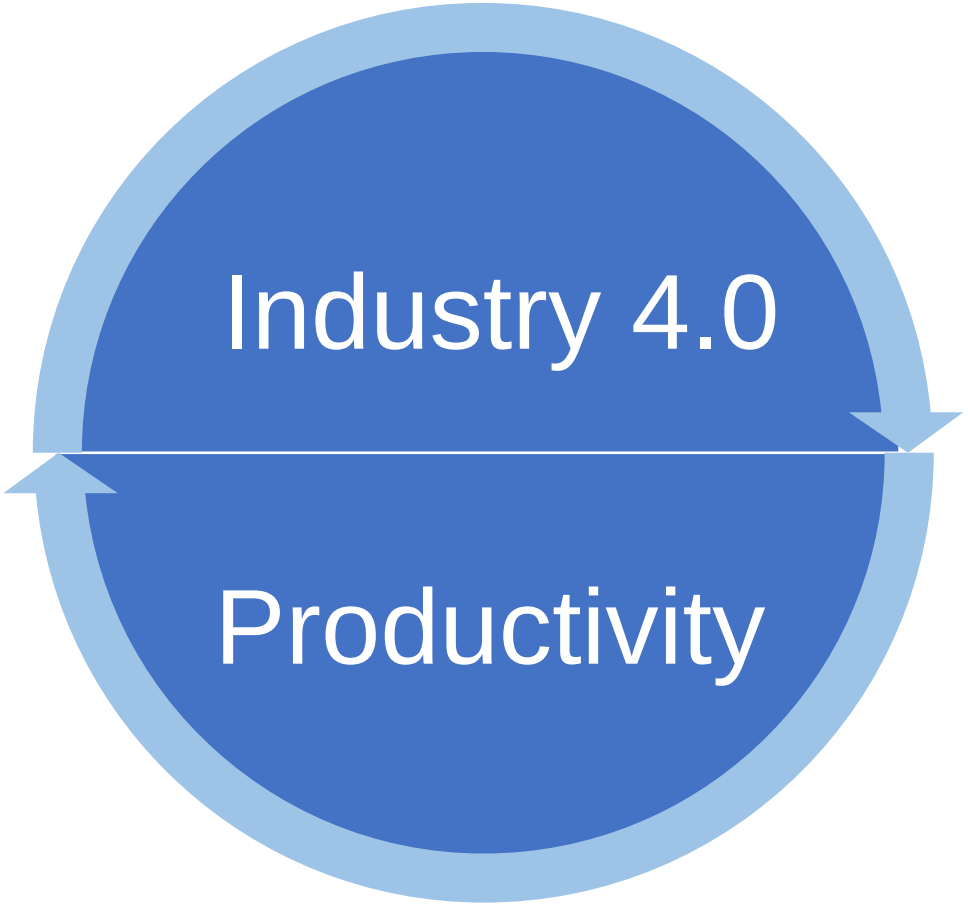
- They can be beneficial as they might generate new jobs and boost economic performance (e.g. value added and productivity).
- Not all countries/sectors/individuals adapt (to) new technology equally fast or successfully. This may have many reasons (e.g. political or 'structural', …).
- Innovative changes are rarely unambiguously positive. Negative effects may occur on the level of the individual, sector, country.

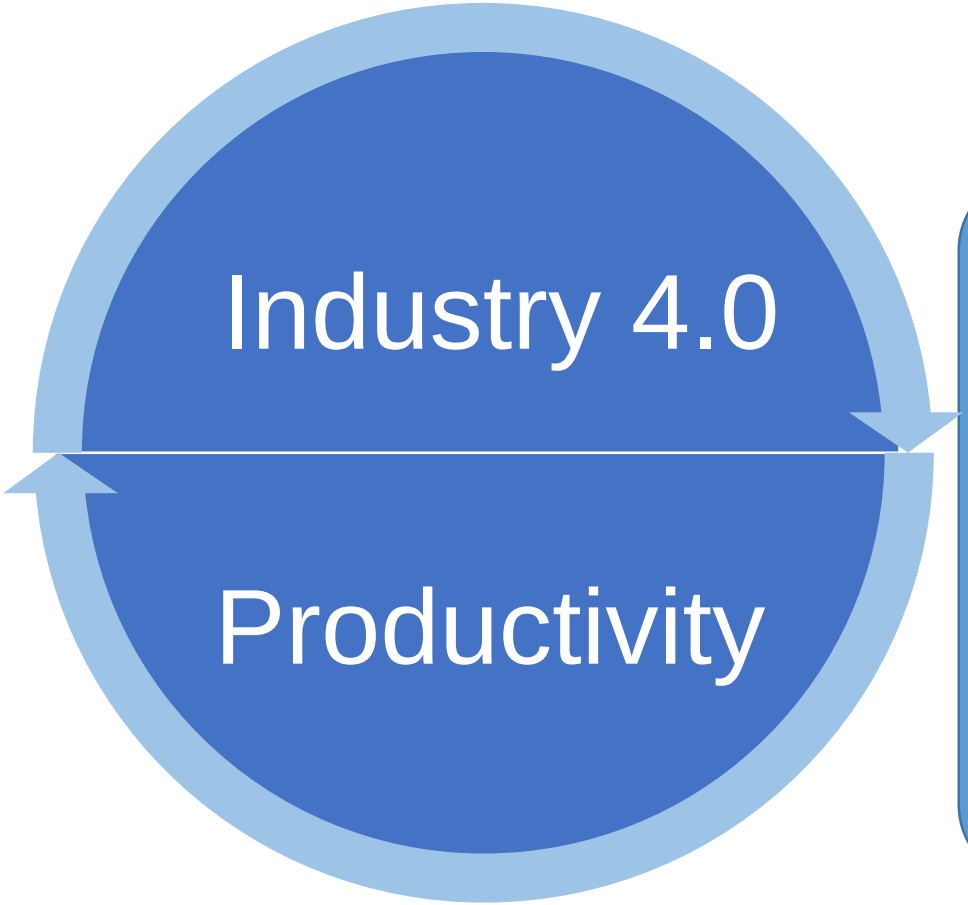
In the context of Industry 4.0

- Policy makers are eager to adopt industry 4.0 technologies to 'jump on the bandwagon' of the unfolding industrial revolution …
  - …in the hopes of boosting economic performance (productivity).
  - …in the fear of otherwise falling behind in this inevitable process.

- There is widespread fear that the adoption of industry 4.0 technology will do very little to boost employment ('jobless growth').
  - We will see in the next session that industry 4.0 is new, but it's not a stand-alone technology.
  - In simple terms: We have had machines already; now with 4.0 we make them smart.
  - Have new technologies negatively affected manufacturing (particularly employment)?

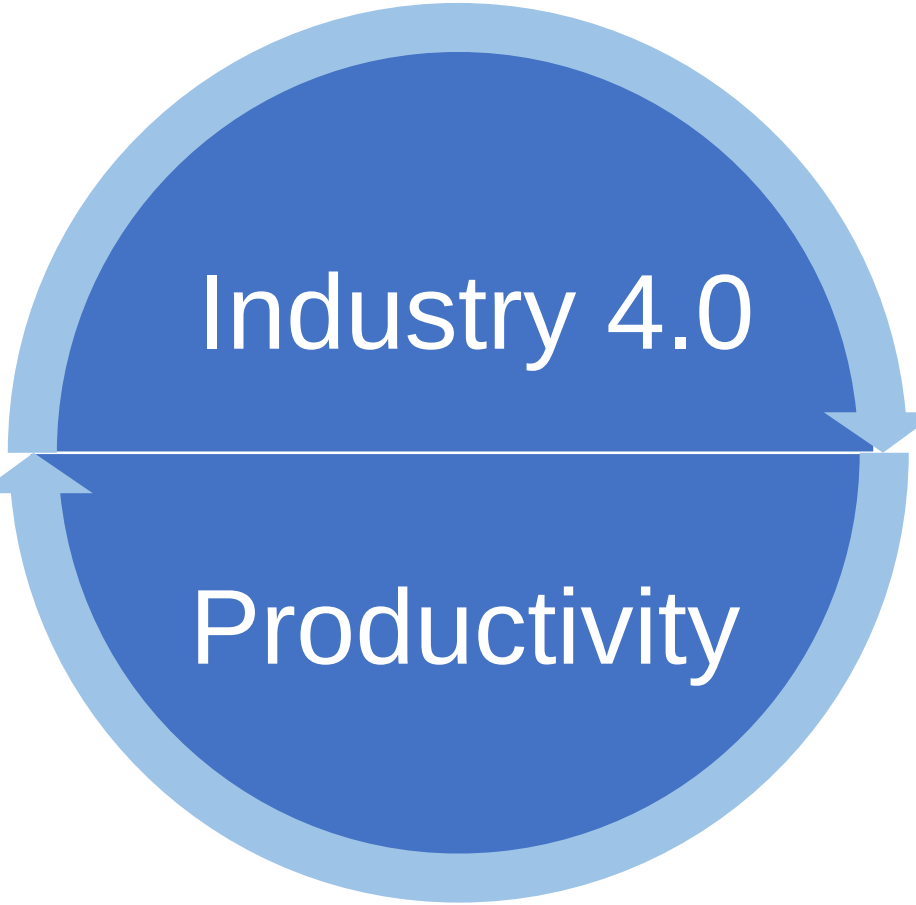

New technologies
Productivity


Industry 4.0
Productivity



New technologies will only be adopted if they 'pay off', i.e. increase productivity.

Adoption of new technologies will affect macroeconomic variables (value added and employment).



Development patterns inform new technology.

Pursuit of productivity growth leads to the development of new technologies.

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Industry 4.0

Capabilities and Prerequisites

Productivity

New technologies will only be adopted if they 'pay off', i.e. increase productivity.

Adoption of new technologies will affect macroeconomic variables (value added and employment).

- What do we mean by Industry 4.0 in this tool?
- How is a country adopting these technologies?
- Do the patterns vary across countries?

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- What are the consequences of technology adoption?
- How have manufacturing industries reacted?

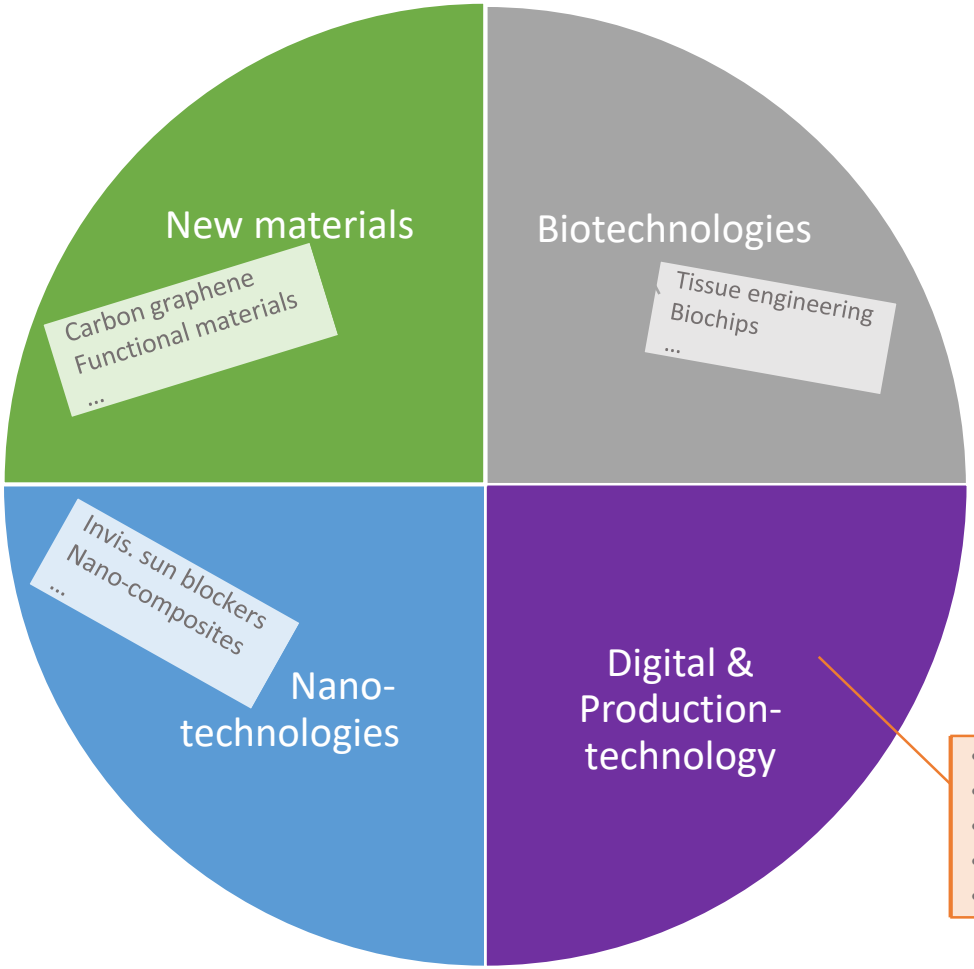
Data

- As for all EQuIP tools the data should
  - Be freely available
  - Have good cross-country coverage
  - Be comparable

- For what remains, we focus on the tangible aspect of modern production technology (because of the above reasons).

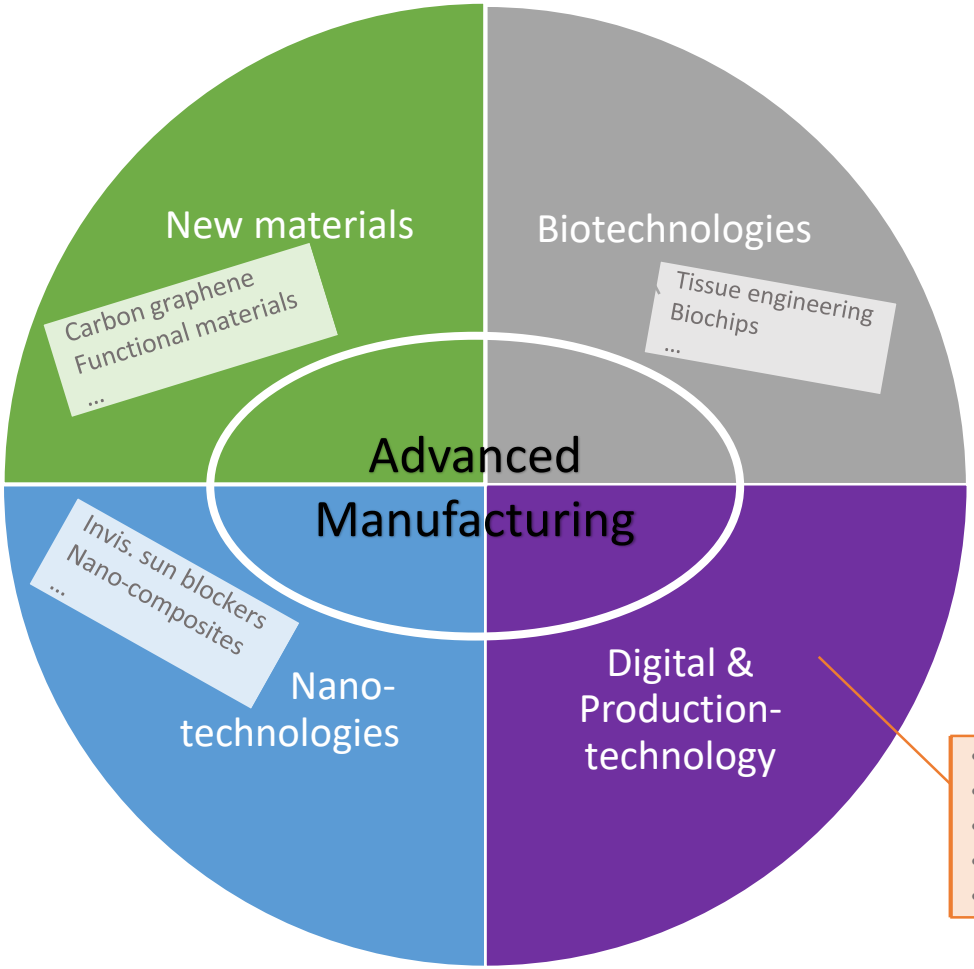
- The proposed concepts may however also be suited to a more specific question to which you may wish to apply your own data.

New technologies



- Big data analytics
- Machine learning
- Artificial intelligence
- Internet of Things (IoT)
- …

New technologies



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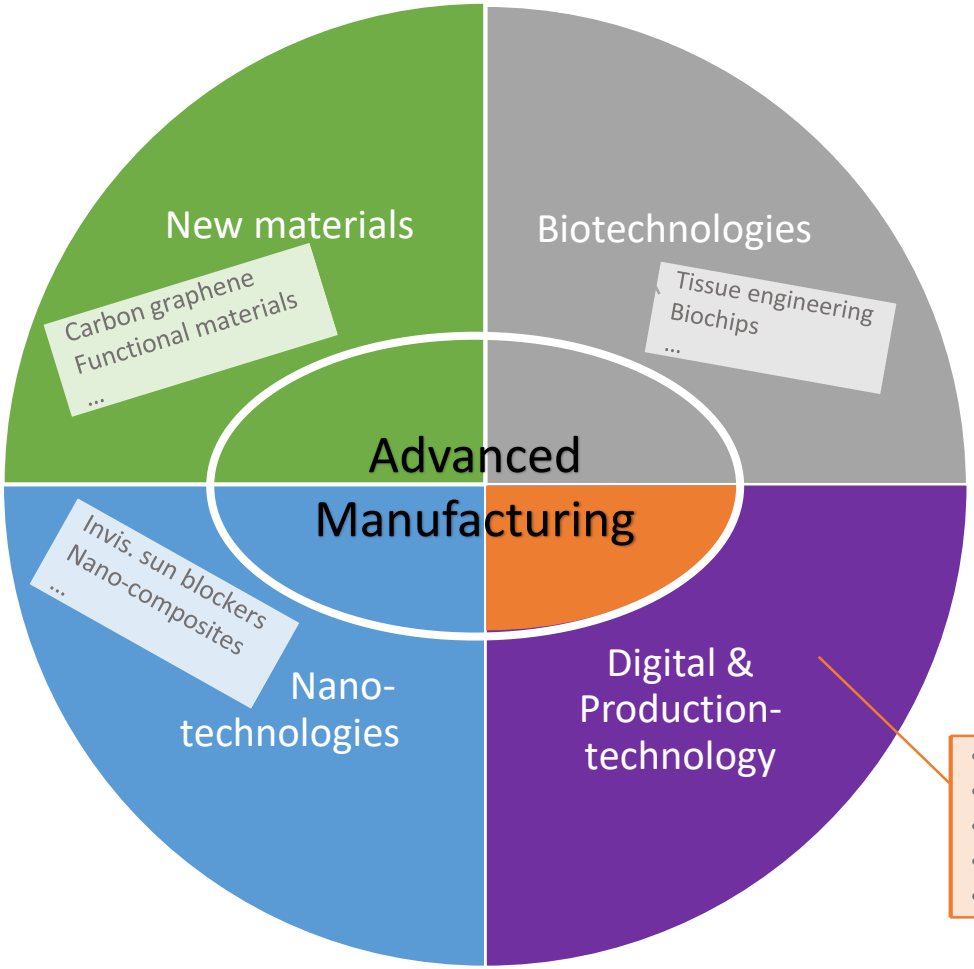
New technologies



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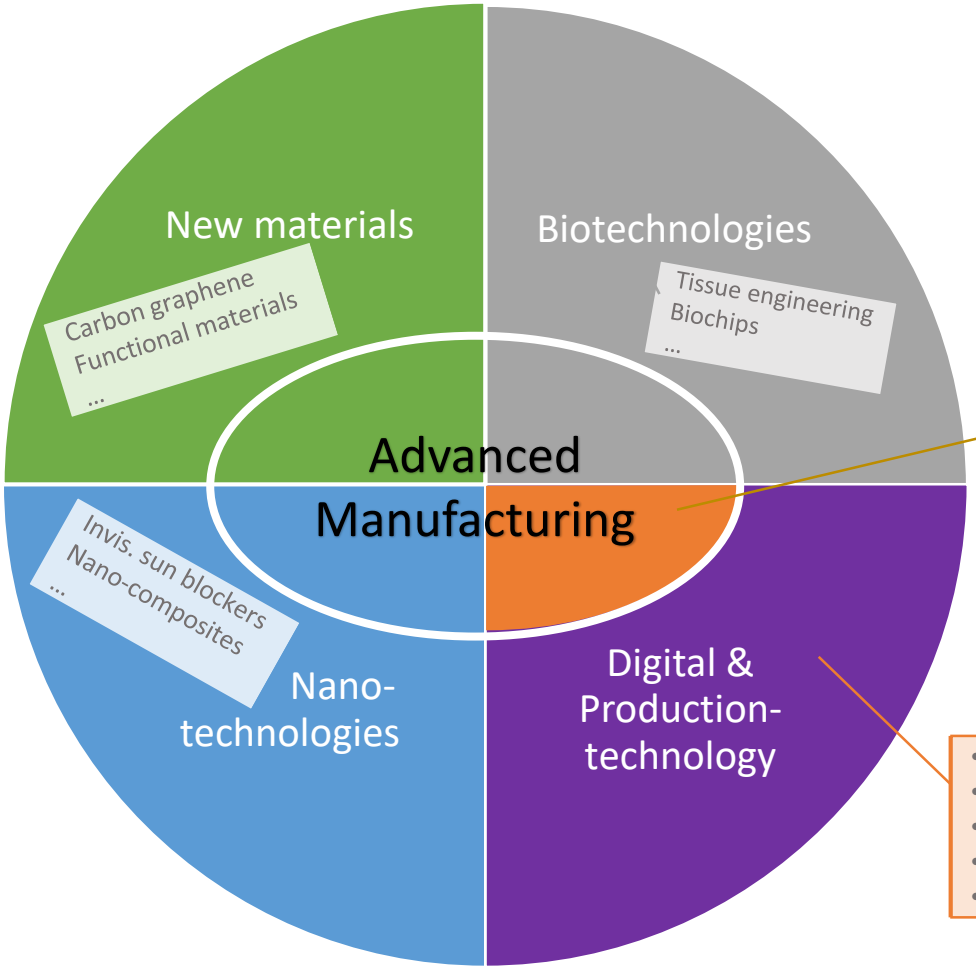
New technologies



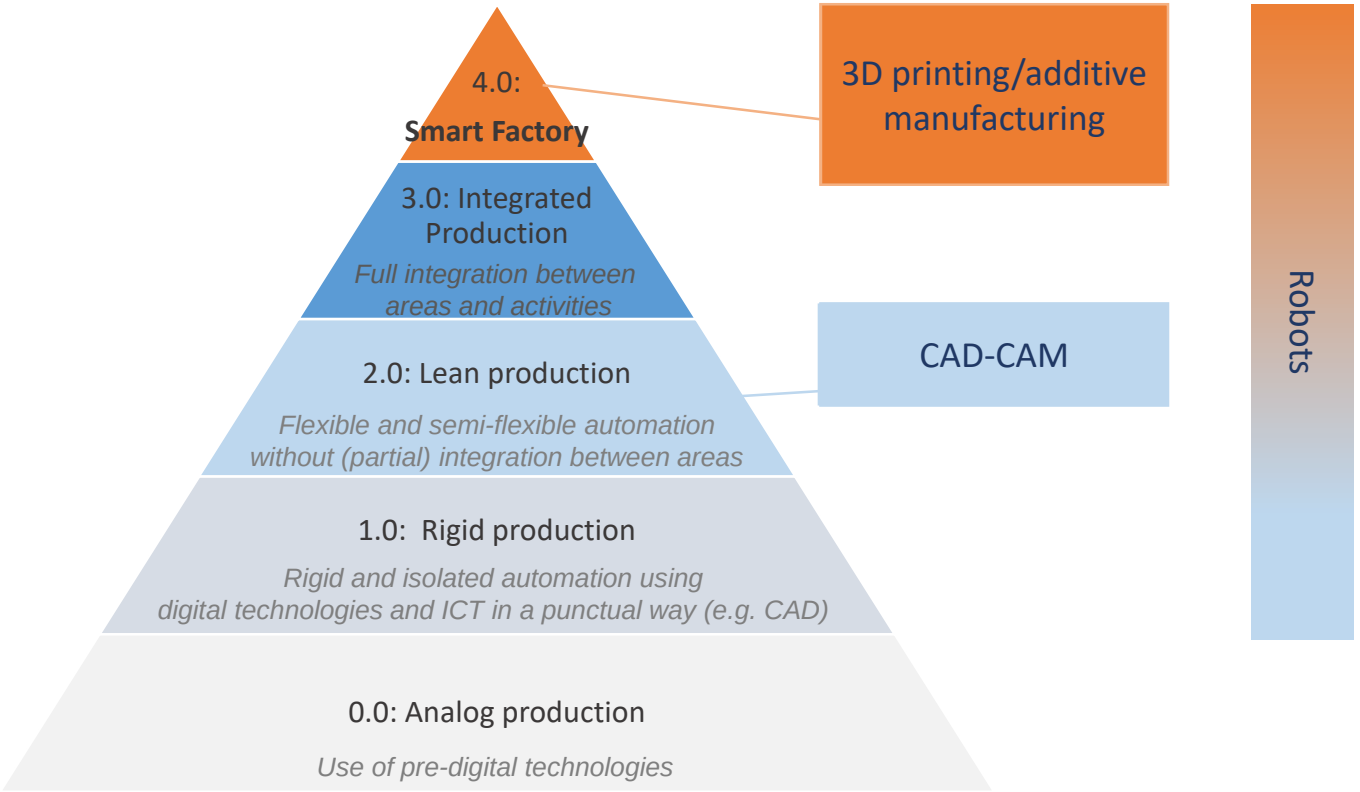
Digital & production technology applied to manufacturing

Smart Factory:

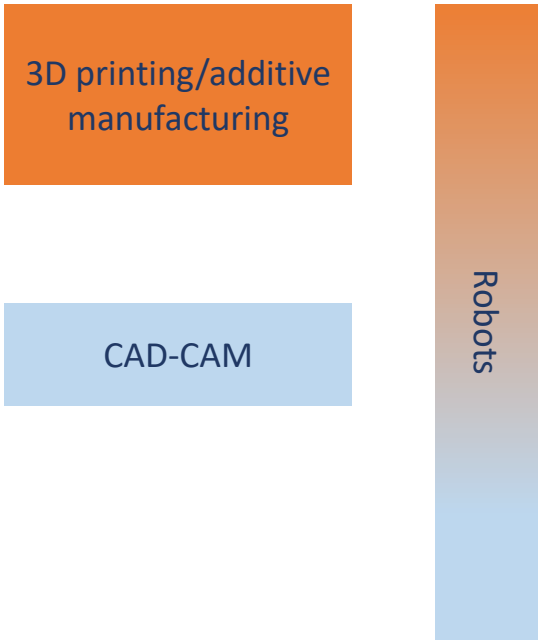
- 3D printing/additive manufacturing
- CAD-CAM
- Robotics
- Industrial IoT
- etc.

- Big data analytics
- Machine learning
- Artificial intelligence
- Internet of Things (IoT)
- ...

Manufacturing technologies

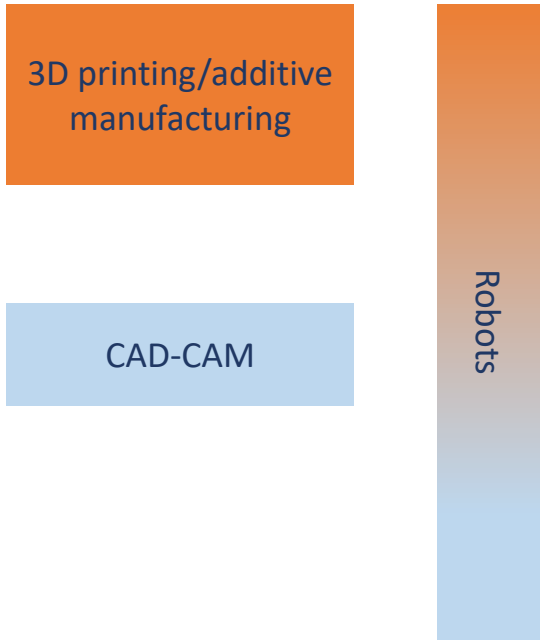


How can we quantify a country's performance?



How can we quantify a country's performance?

- The main idea:
  - Analyse certain components of a particular set of goods



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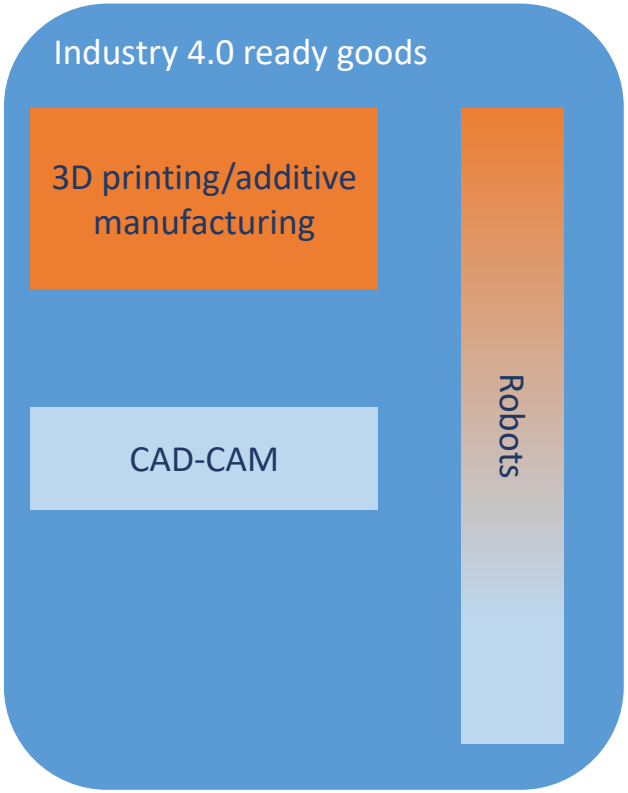

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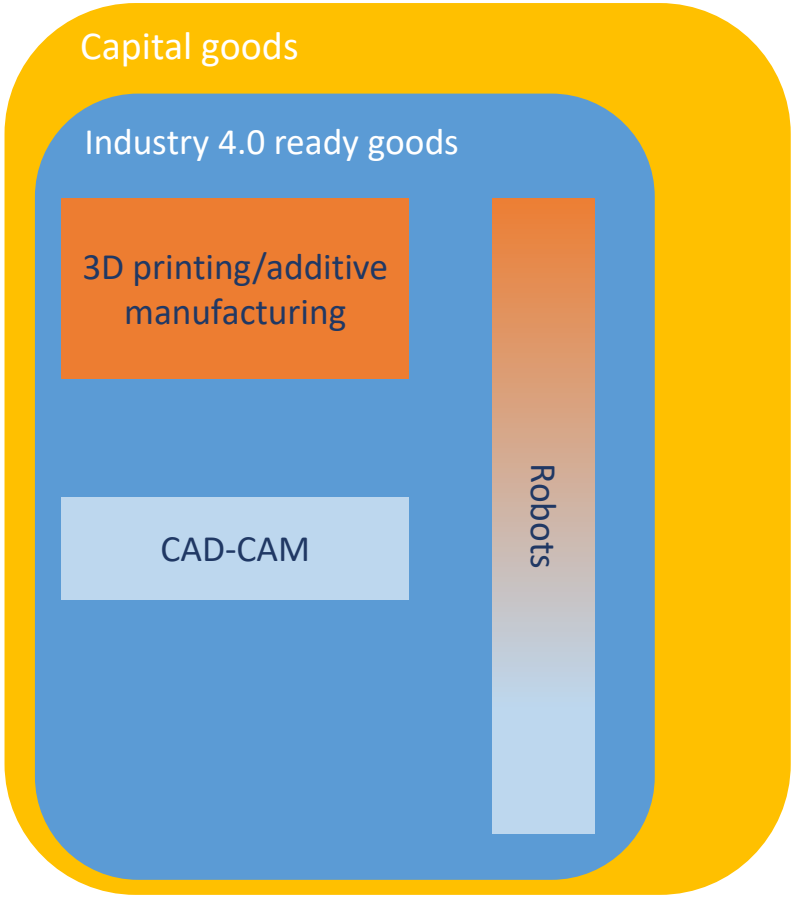
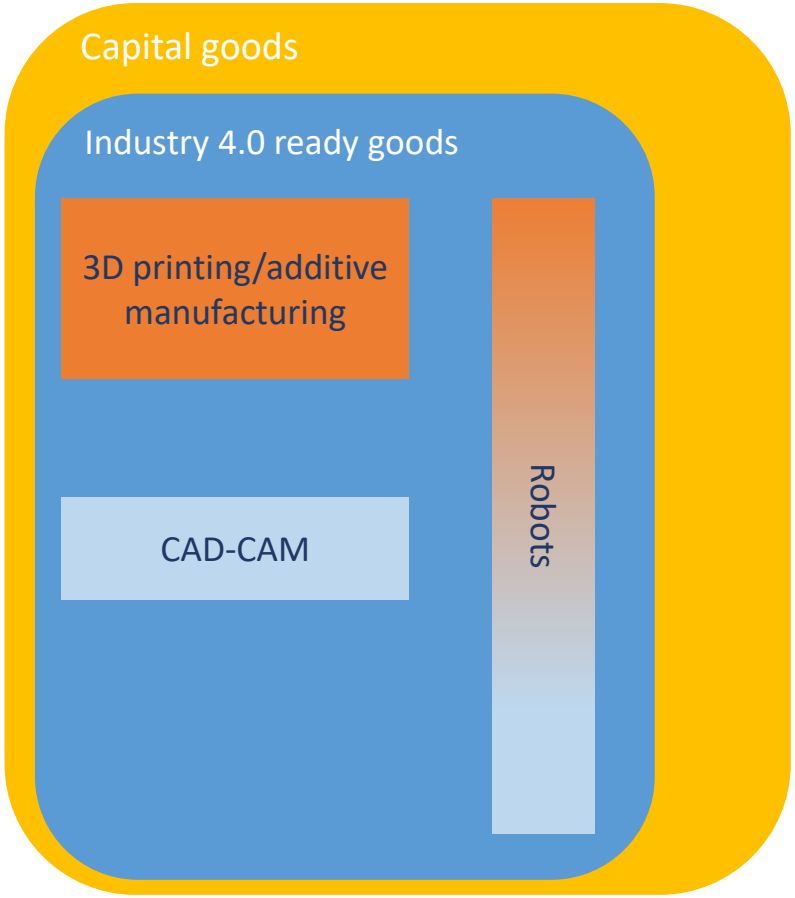


How can we quantify a country's performance?

- The main idea:
  - Analyse certain components of a particular set of goods

- Derive indicators to
  - quantify the degree of adoption of industry 4.0-ready technologies;
  - identify and differentiate countries through their adoption strategy;
  - monitor employment creation/displacement effects.

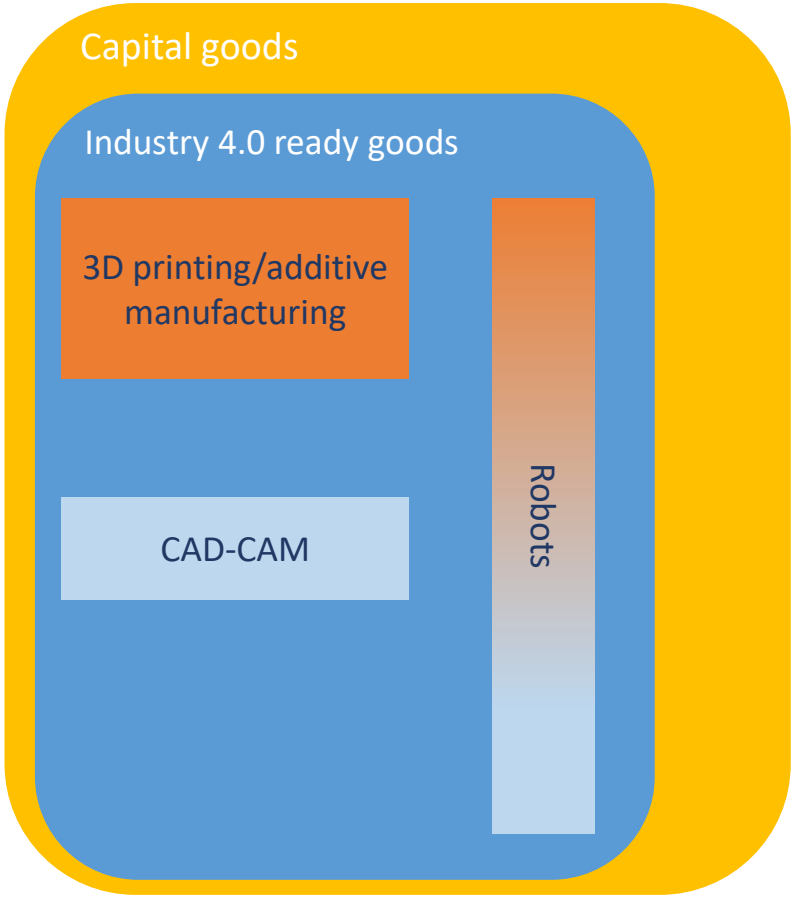


Technology Adoption

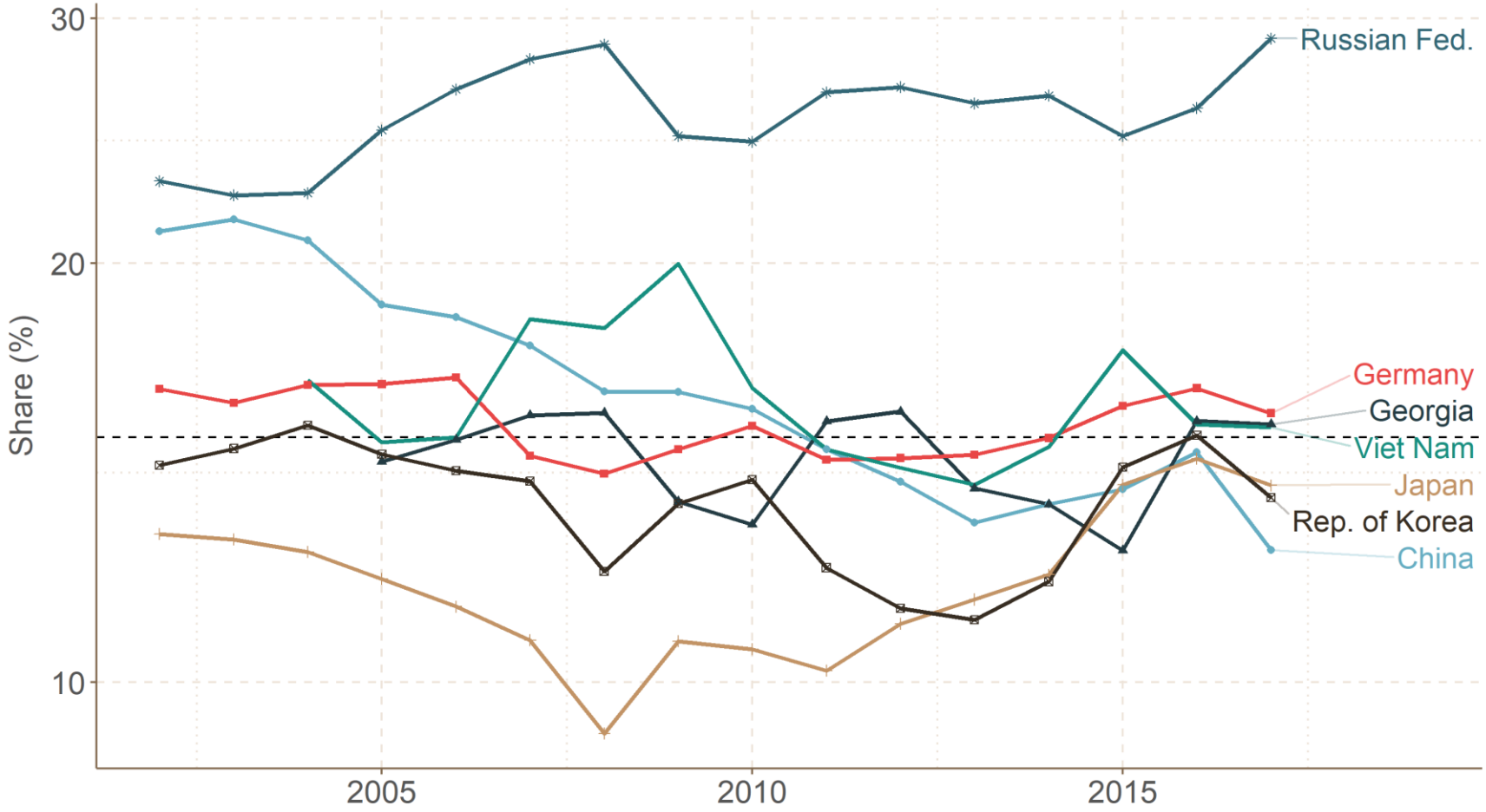
To what degree is a country integrated in the adoption of advanced technologies?

Motivation

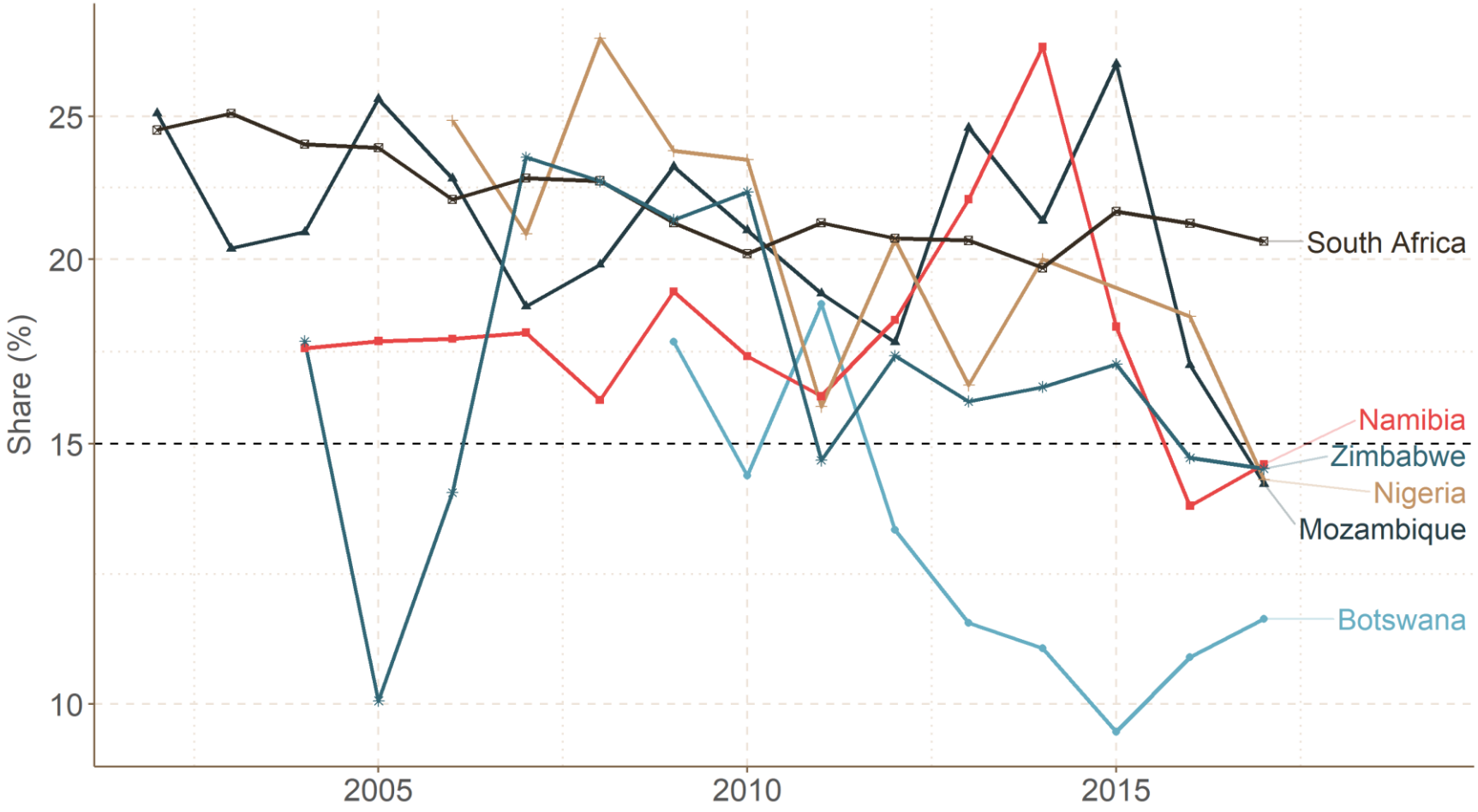
- Question(s)
  - Is my country adopting advanced technologies
- These technologies can be
  - Developed and produced domestically
  - Imported (embodied in machines)
- Data
  - National firm level (ideally)
  - Trade data to capture cross-country dimension
  - Here: focus on capital goods and I4.0 goods



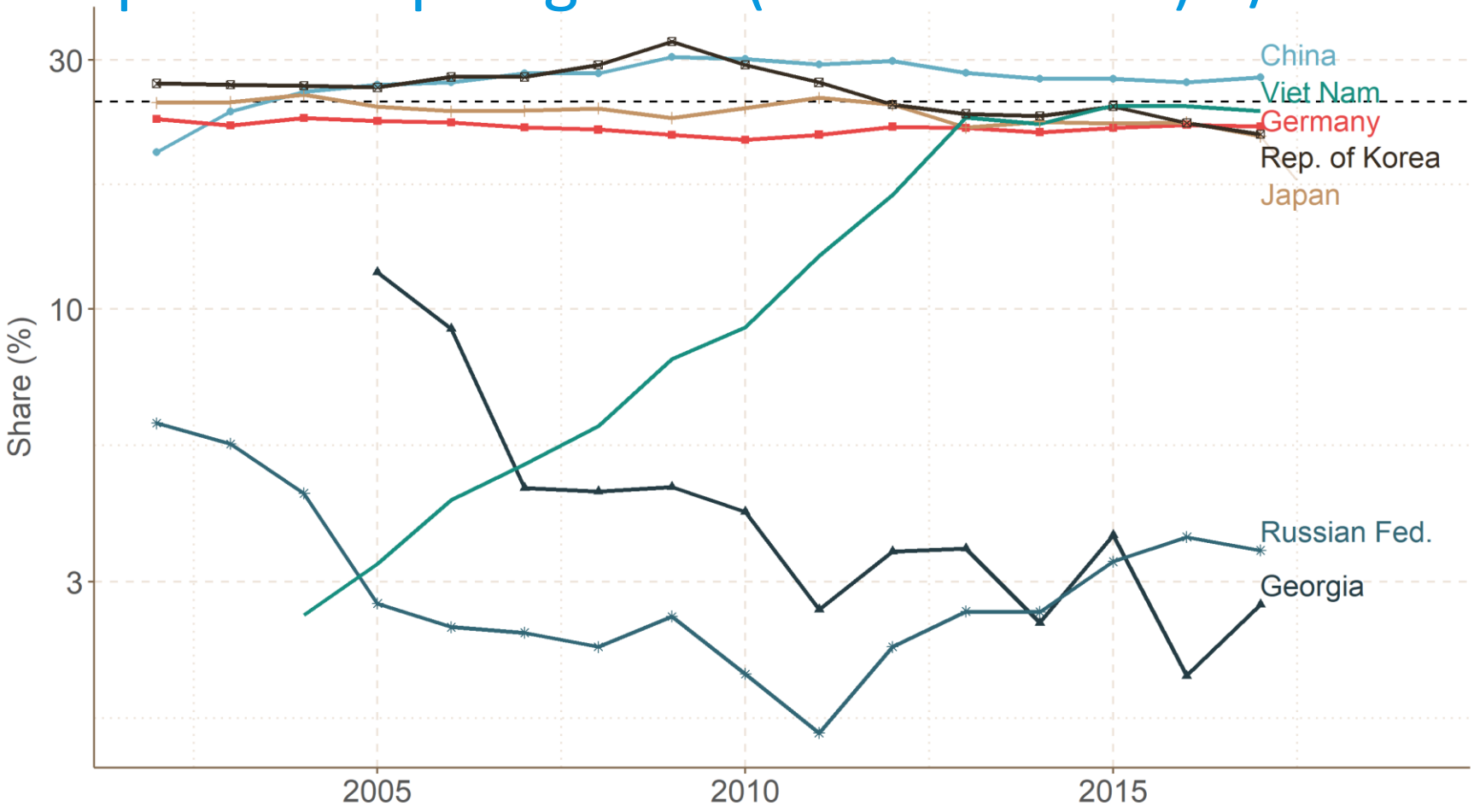
Imports of capita goods (share of total) 1/2



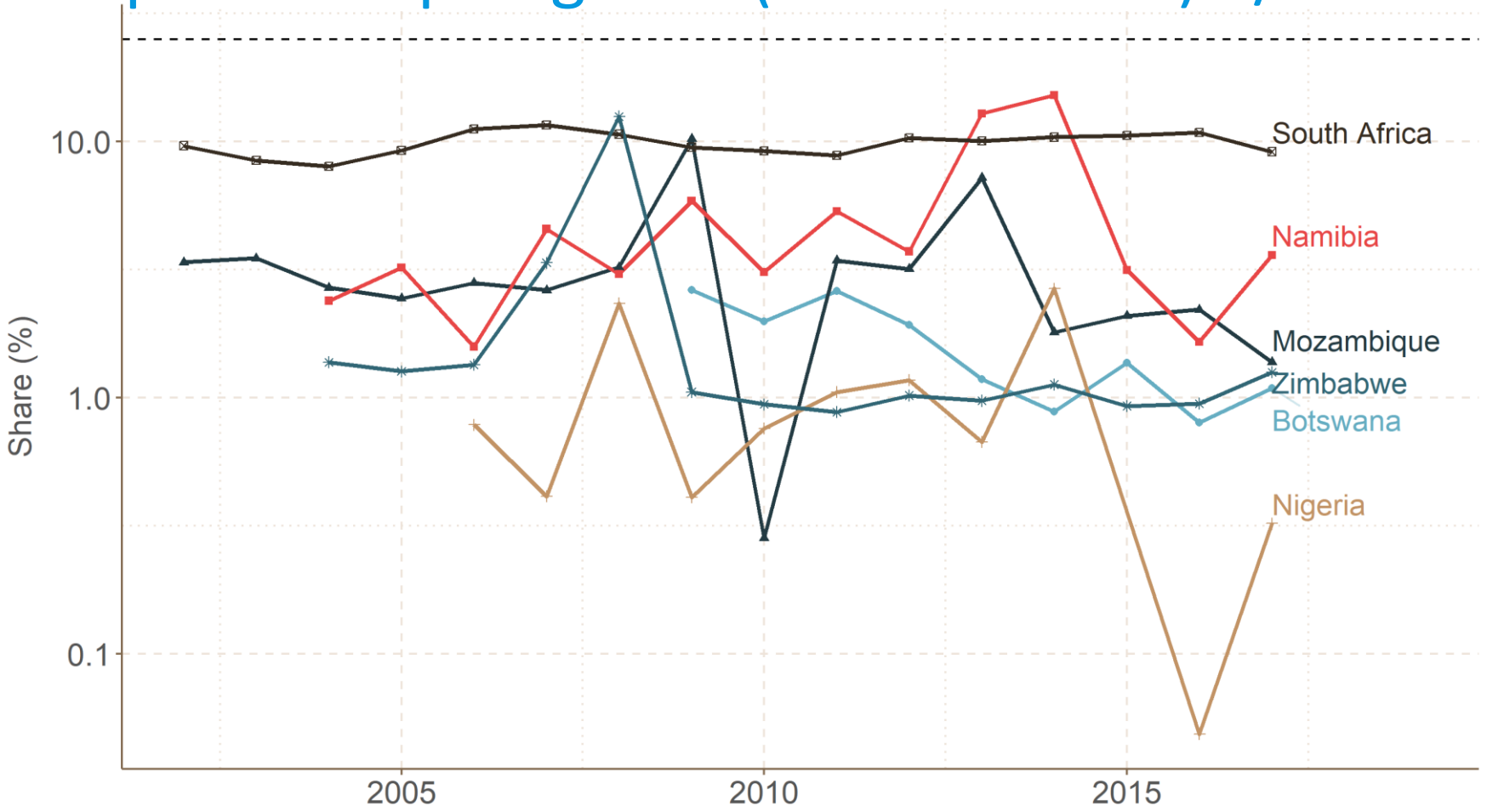
Imports of capita goods (share of total) 2/2



Export of capita goods (share of total) 1/2



Export of capita goods (share of total) 2/2

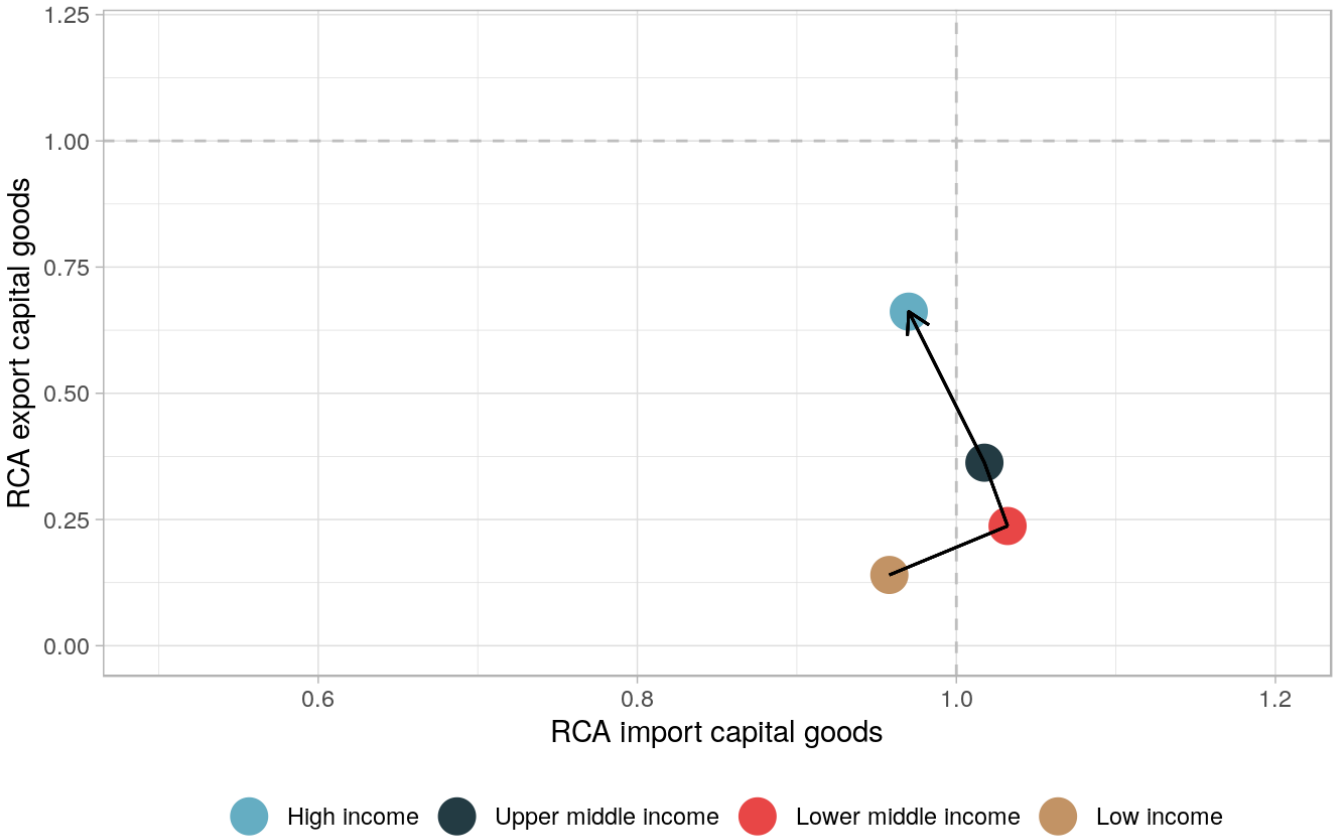


Import/Export of capita goods

- Can we put this into perspective?

- We consider the imports and export relative to the world average.
  - The Revealed Comparative Advantage (RCA) considers import/export performance in relation to the global trend.
  - If RCA > 1 performance is above world average.
  - IF RCA < 1 performance is below world average.

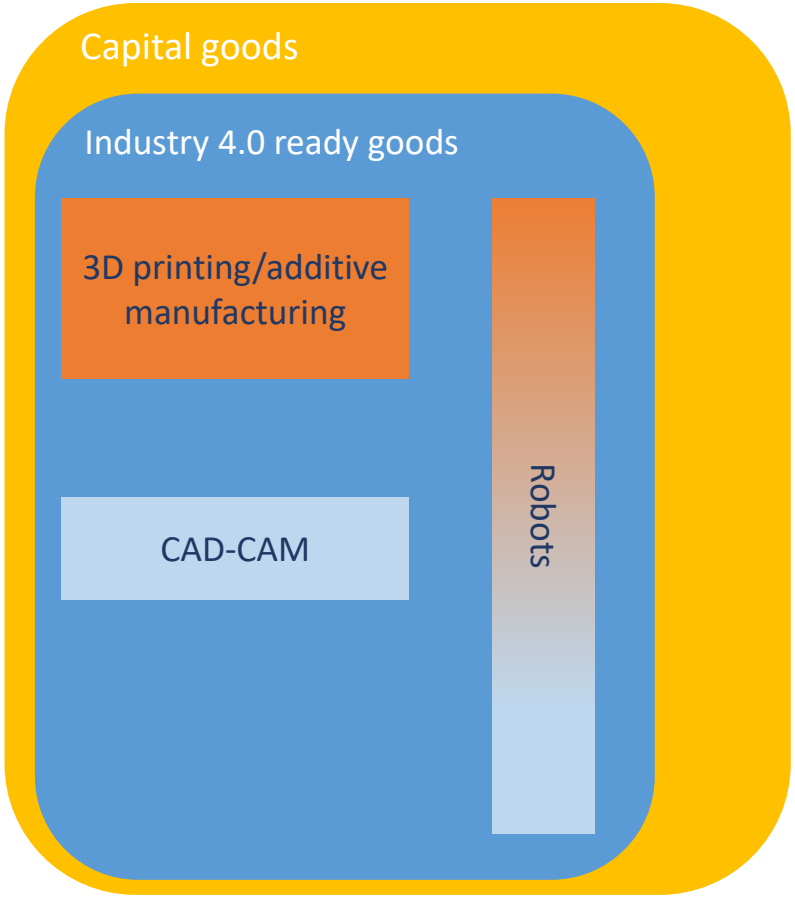
Empirical regularity: RCA by income group



- The higher a country's income, the more they export capital goods.
- Countries average import of capital goods is highest for the lower middle income group.

Generalisation

- This approach can easily be generalised.
- Granular goods classification allows for a detailed analysis:
  - Analysis of Industry 4.0 ready goods;
  - Or components thereof.



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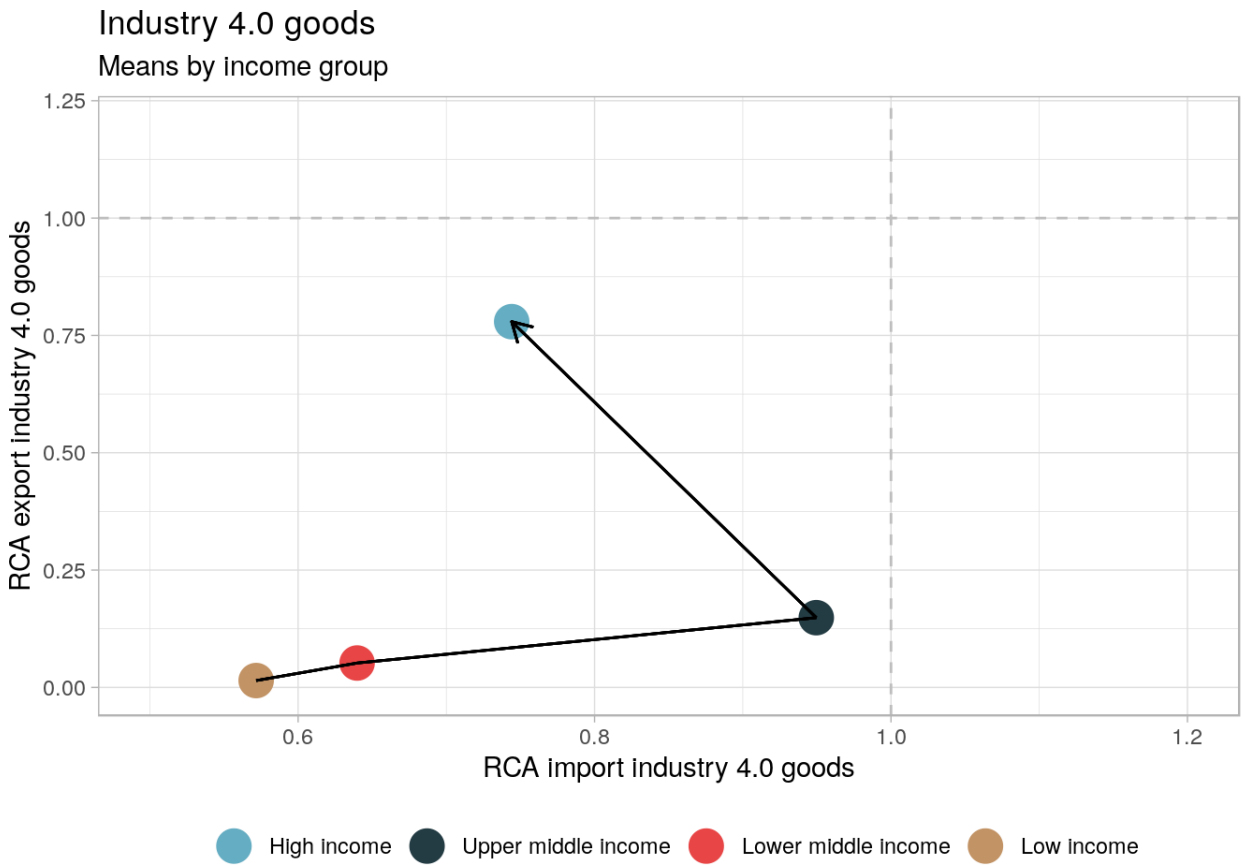

- A similar yet more skewed picture emerges.
- The higher a country's income, the more they export Industry 4.0 goods.
- Exports are highly concentrated.

Technology adoption: summary

- Analysis of relative and absolute import and export performance across countries.
- Different types of goods and categorisation allow for the comprehensive cross-country analysis.
- Analysis may be conducted on very specific sub-classification on Industry 4.0 goods as well.
  - 'What is the performance in 3D printing?'
- Flexible framework that can easily be extended by domestic firm-level data on goods groups of interest.
  - Cross-country comparability subject to data availability.

Robotization

Are jobs at risk of being replaced by new technology?

What is one of the biggest fears for employees and policy makers when they think about robots?

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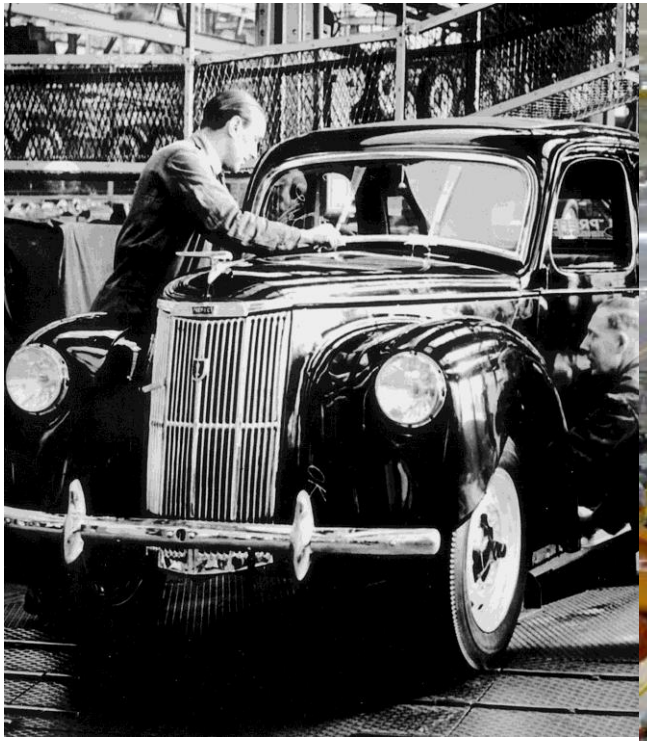
That this (5 cars, 9 people)….

What is one of the biggest fears for employees and policy makers when they think about robots?



That this (5 cars, 9 people)….

…turns into this (7 cars, 0 people).

What kind of robots are we talking about?

- Industrial robots as defined by the International Federation of Robotics:
  - An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications
  - See ifr.org/industrial-robots for more information.
  - Selected examples on the right.

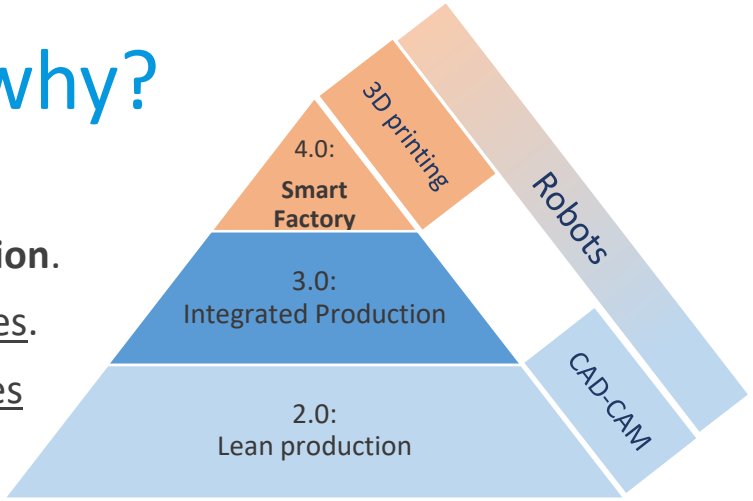

Welding


Painting


Packaging

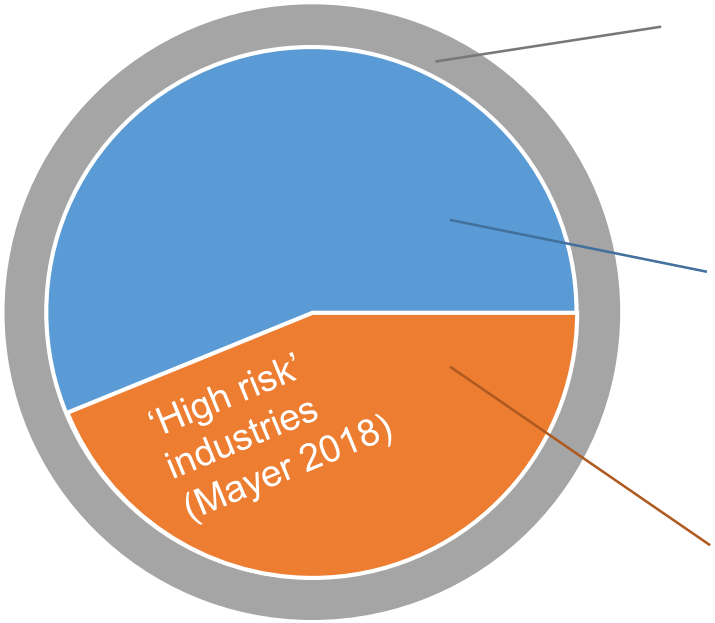

Handling for forging

Industrial robots: what and why?



- How is this different to industry 4.0 technology?
  - Robots cover a **broader range of manufacturing production**.
  - We use stock data on the level of manufacturing industries.
  - We can identify the number of robots per worker, changes over time and differences across industries.
- Analysis also goes one step further in terms of technology adoption:
  - If we only look at the number of imported robots we don't know if/how firms use them.
  - Provides insights into how robotization changes the composition of **production input factors.**
  - This is of high relevance for developing countries.
- Disclaimer
  - No data for African countries on industrial robots: analysis lacks one dimension (see next slide).
  - Data set currently not free of charge.

Robotisation: capacity and job loss

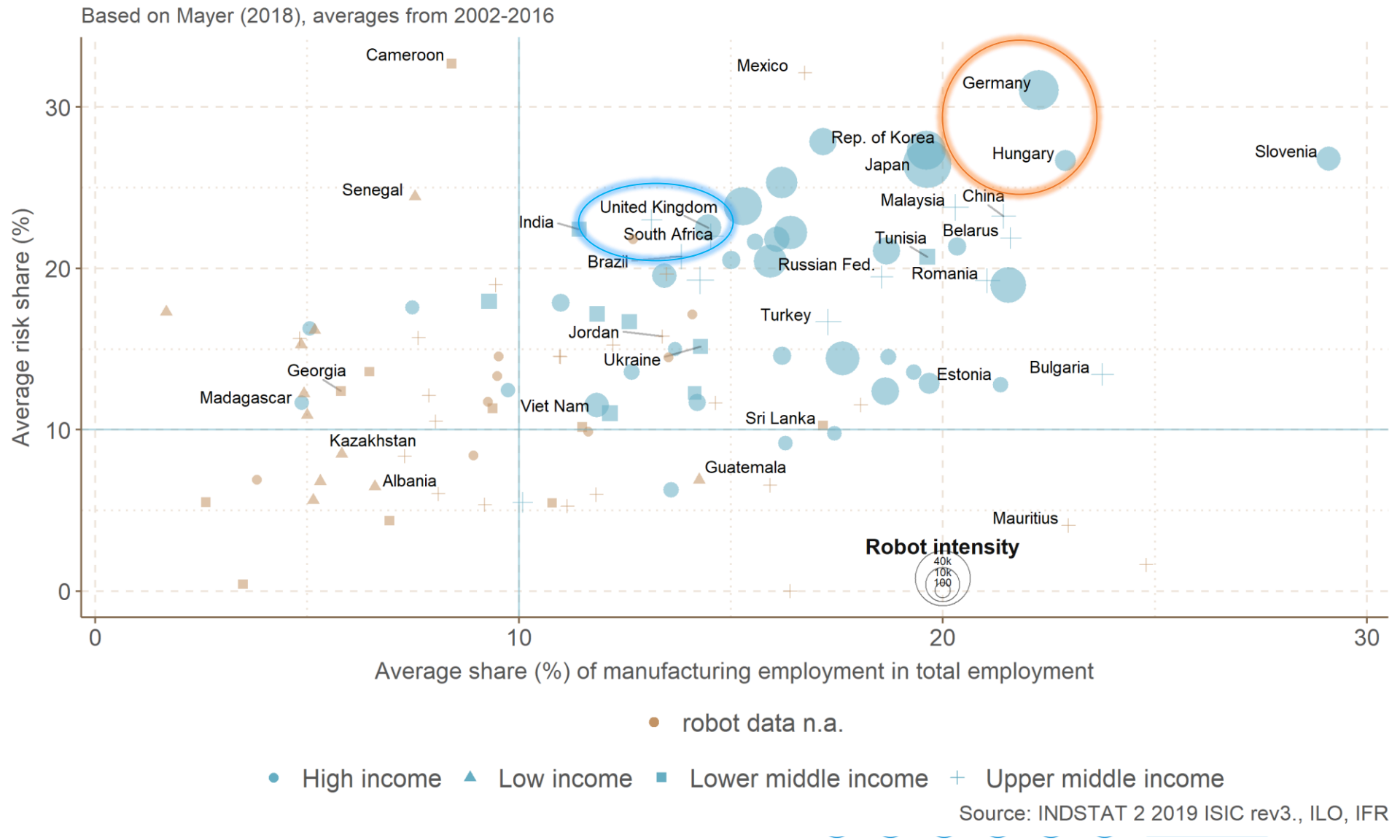


Size of manufacturing sector (manufacturing share)
- 'How many people are potentially affected?'

Degree of automation (robot intensity)
- 'How intensely are robots used in an industry?'
- Not available for Africa because of lack of data.

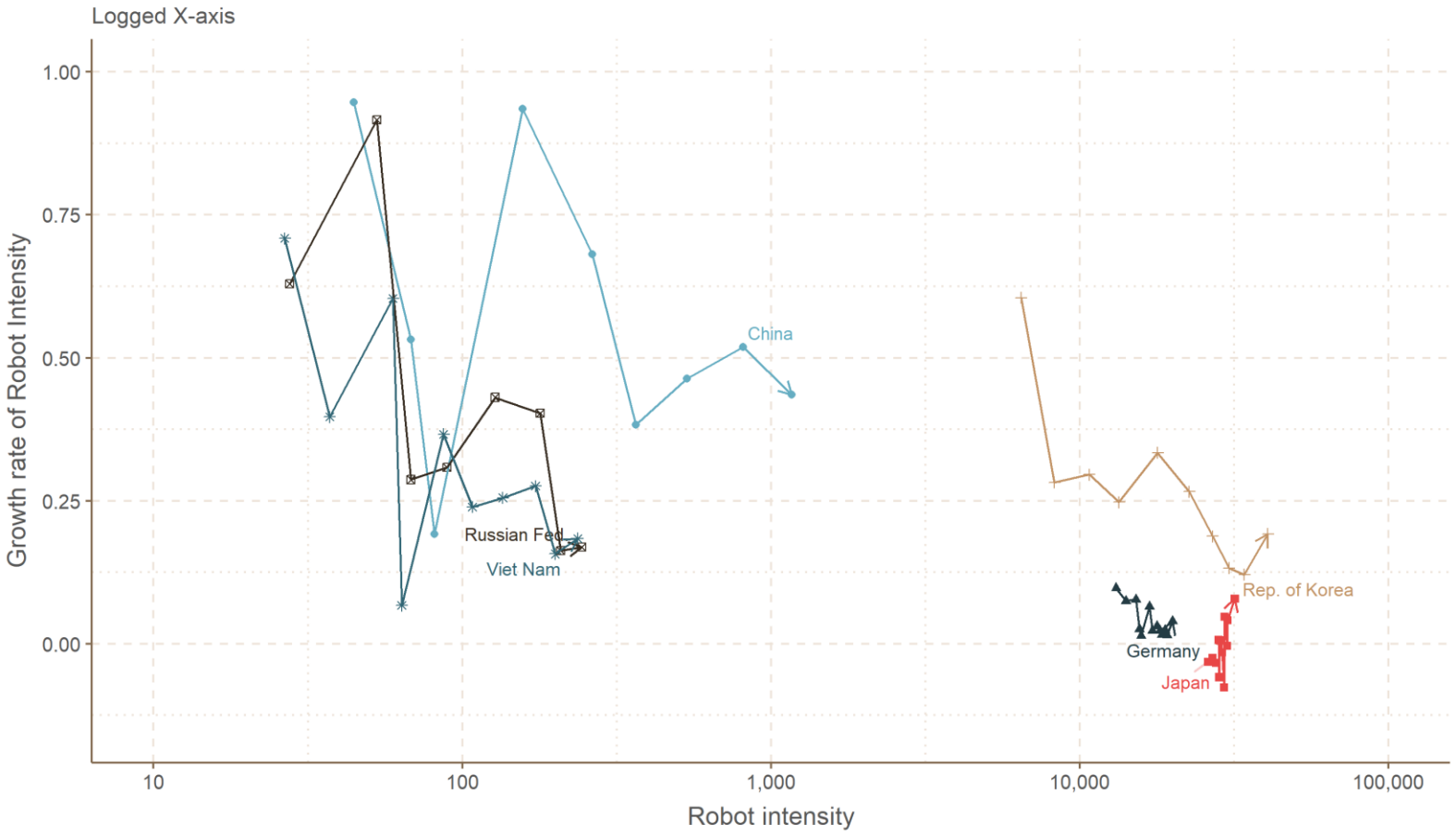
Size of 'risk industries' as part of manufacturing
- Defined by Mayer (2018) as:

Chemicals	**Rubber and Plastic**
Electronic Appliances	**Automobiles**



Source: INDSTAT 2 2019 ISIC rev3., ILO, IFR

Maturity in robotisation



Source: IFR, ILO

Robotisation: summary

- The risk of job loss due to robotization may be higher
  - The larger the manufacturing sector is
  - The larger the share of activities is robots can perform (with the latest, smartest generation of robots this share naturally increases)
  - The higher the growth rate of the number of robots per employee (active replacement)
- Robotisation (as most new technologies) will also lead to the creation of new jobs; however, they
  - Will probably not allow for a 1-to-1 job transitioning for the same worker(s)
  - May be at least temporarily socio-economically costly (e.g. re-training, unvoluntary unemployment)

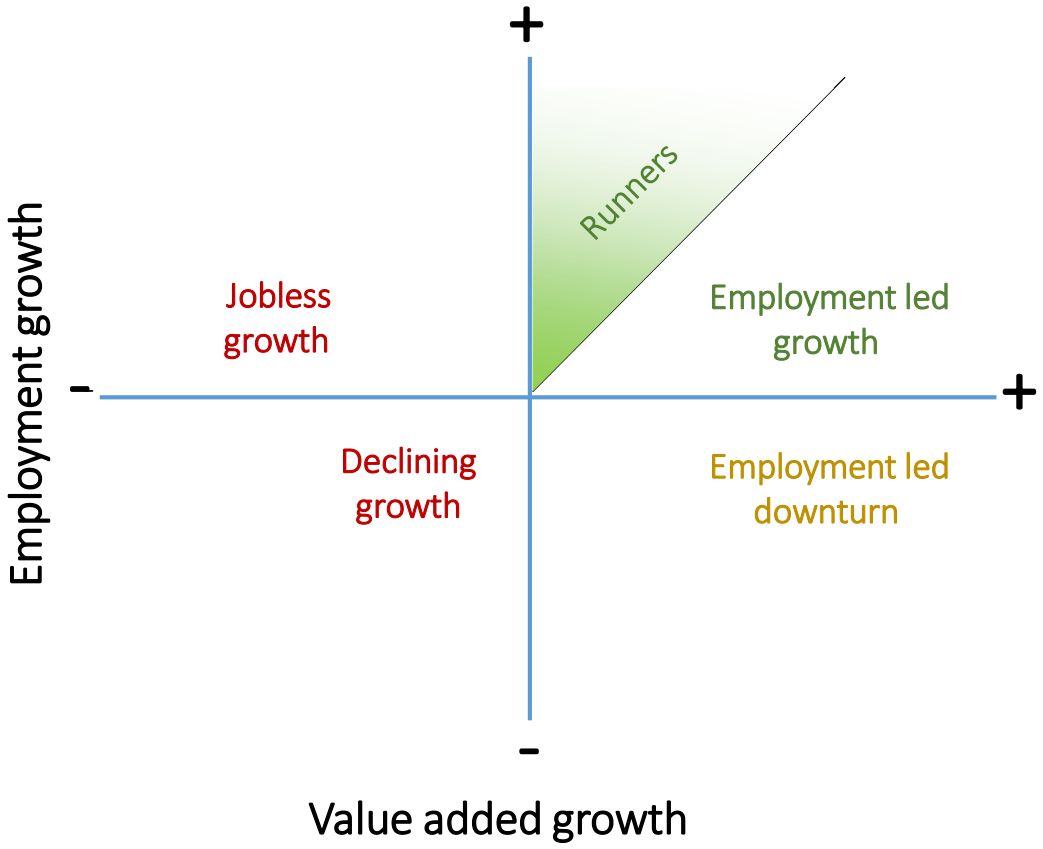
Runner industries

Will new technologies inevitably lead to ‘jobless’ growth?

Runner industries

- Question(s)
  - What are the productivity growth dynamics of a particular industry and what do they depend on?
  - Are positive productivity growth rates always good?
  - Is 'jobless growth' in manufacturing inevitable?
- Policy relevance
  - There is always a growth trade-off:
    - $growth(productivity) \approx growth(value\ added) - growth(employment)$
  - We define industries with a positive productivity and employment (and therefore value added growth) growth rate as runner industries.

Runner industries visualized



Global runners

- Consider the overlap with 'high risk' industries identified in the previous part!

Runner industries: Global runners for the post-2000 sample period.

Manufacturing Industries	Productivity CAGR	VA CAGR	Employment CAGR	Global runner
15: Food and beverages	0.39	1.07	0.46	Yes
16: Tobacco	1.50	-1.63	-3.68	
17: Textiles	1.19	-2.72	-4.18	
18A: Wearing apparel	-0.03	-2.29	-2.57	
20: Wood products	0.16	-0.56	-0.93	
21: Paper	1.29	0.65	-0.75	
22: Printing and publishing	2.68	-0.51	-3.30	
23: Coke and refined petroleum	-1.74	-2.06	-0.23	
24: Chemicals	2.05	2.46	0.15	Yes
25: Rubber and plastic	0.90	2.03	1.06	Yes
26: Minerals	1.13	0.99	-0.68	
27: Basic metals	0.30	-0.51	-1.11	
28: Fabricated metals	0.31	1.37	0.75	Yes
29C: Machinery	3.32	3.39	-1.55	
31A: Electrical machinery	1.14	3.96	1.35	Yes
33: Precision instruments	3.15	4.86	0.97	Yes
34A: Motor vehicles	1.36	2.90	1.64	Yes
36: Furniture, n.e.c	-0.20	0.13	0.26	

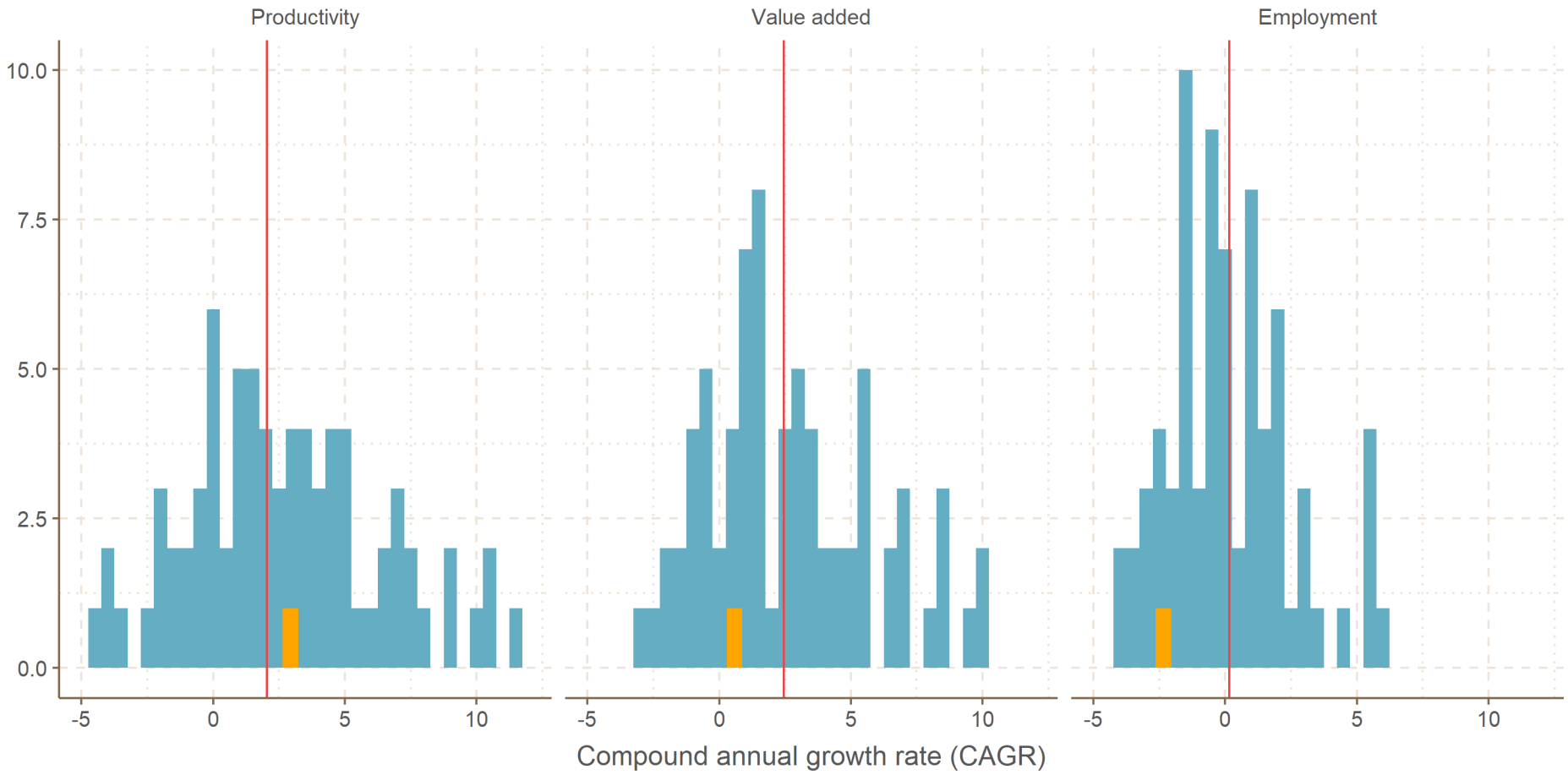
South Africa Runners

- No runner industries identified.
- Productivity increases result of negative employment growth.
- Chemicals:
  - More productive than the global average.
  - The only industry with positive VA growth
  - Characterised by jobless growth.

	South Africa			
Manufacturing industry	**Productivity CAGR**	**VA CAGR**	**Employment CAGR**	**Runner**
17: Textiles	-1.51	-6.98	-5.56	
18A: Wearing apparel	-2.64	-8.65	-6.17	
20: Wood products	2.74	-0.27	-2.93	
21: Paper	-0.16	-2.43	-2.28	
23: Coke and refined petroleum	-1.41	-1.86	-0.46	
24: Chemicals	2.65	0.49	-2.10	
25: Rubber and plastic	1.64	-0.55	-2.15	
26: Minerals	0.44	-2.17	-2.60	
27: Basic metals	1.83	-3.33	-5.07	
28: Fabricated metals	-1.34	-1.60	-0.26	
31A: Electrical machinery	1.94	-2.46	-4.32	
33: Precision instruments	-2.68	-2.31	0.38	
34A: Motor vehicles	-0.77	-1.45	-0.68	

Industry profiling: Chemicals

Sector 24: Chemicals.



INDSTAT 2 rev.3, 1963-2017.
Red vertical lines illustrate mean CAGRs of the income group runners.

Linking back to Industry 4.0 adoption

- Through the time dimension of the runner industry analysis one can identify the effect of technology adoption:
  - How and when does country engages with (what kind of) new technology?
  - Is this leading to displacement of workers?
  - Do industries qualify as runners?
    - Does adoption increase productivity and generate employment?
    - How pronounced is this effect relative to benchmarking countries? (quasi-control trial)

Runner industries: summary

- Not all forms of productivity growth are equally desirable
  - Productivity growth itself is not necessarily good (e.g. jobless growth)
  - Not all forms of productivity decline are equally bad (e.g. employment led growth)
- Industry profiling can help understand structural dynamics of an industry in absolute and relative terms
  - It can help assess how similar growth dynamics of (a) particular industry/(ies) across countries
- Time-trajectory can help connect back to adoption process.
- Runner industries are typically medium- to high-technology: They are strongly driven by technological progress.
- Economic growth and the adoption of new technology do not necessarily entail a toll in terms of growth/employment trade-off.

Thank you for your attention

www.equip-project.org

Juergen AMANN

j.amann@unido.org

Appendix

Appendix:
Capital Goods Classification

Classification of capital goods types

System of National Accounts (SNA)

Consumer Goods	Intermediate Goods	**Capital Goods**

Classification of capital goods types

System of National Accounts (SNA)

Consumer Goods

Intermediate Goods

Capital Goods

Capital Goods
[41] + [521]

COMTRADEBEC Classification

Classification of capital goods types

System of National Accounts (SNA)

Consumer Goods

Intermediate Goods

Capital Goods

Capital Goods [41] + [521]

COMTRADEBEC Classification

4.0 ready goods

Non 4.0 Goods

COMTRADE HS Classification

Classification of capital goods types

System of National Accounts (SNA)

Consumer Goods

Intermediate Goods

Capital Goods

Capital Goods [41] + [521]

COMTRADEBEC Classification

4.0 ready goods

Non 4.0 Goods

COMTRADE HS Classification

3D Printing

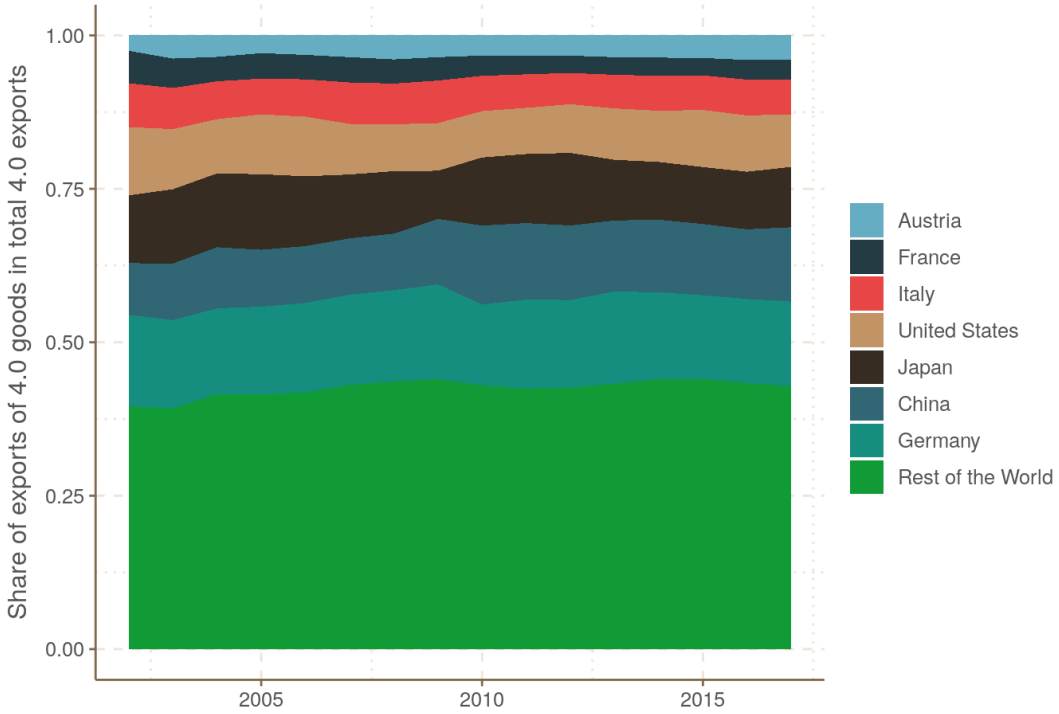
CAD-CAM

Robotics

UNIDO Classification

Appendix: Centralisation of I4.0 Exports

Concentration of I4.0 Exports



Source: UN COMTRADE

Based on UNIDO (2020) and Foster-McGregor, Nomaler, and Verspagen (2019), Industrial Robots (IR), Computer-aided design and manufacturing (CAD-CAM) and Additive Manufacturing (AD) are core industry 4.0 technologies for which there is available data on trade.

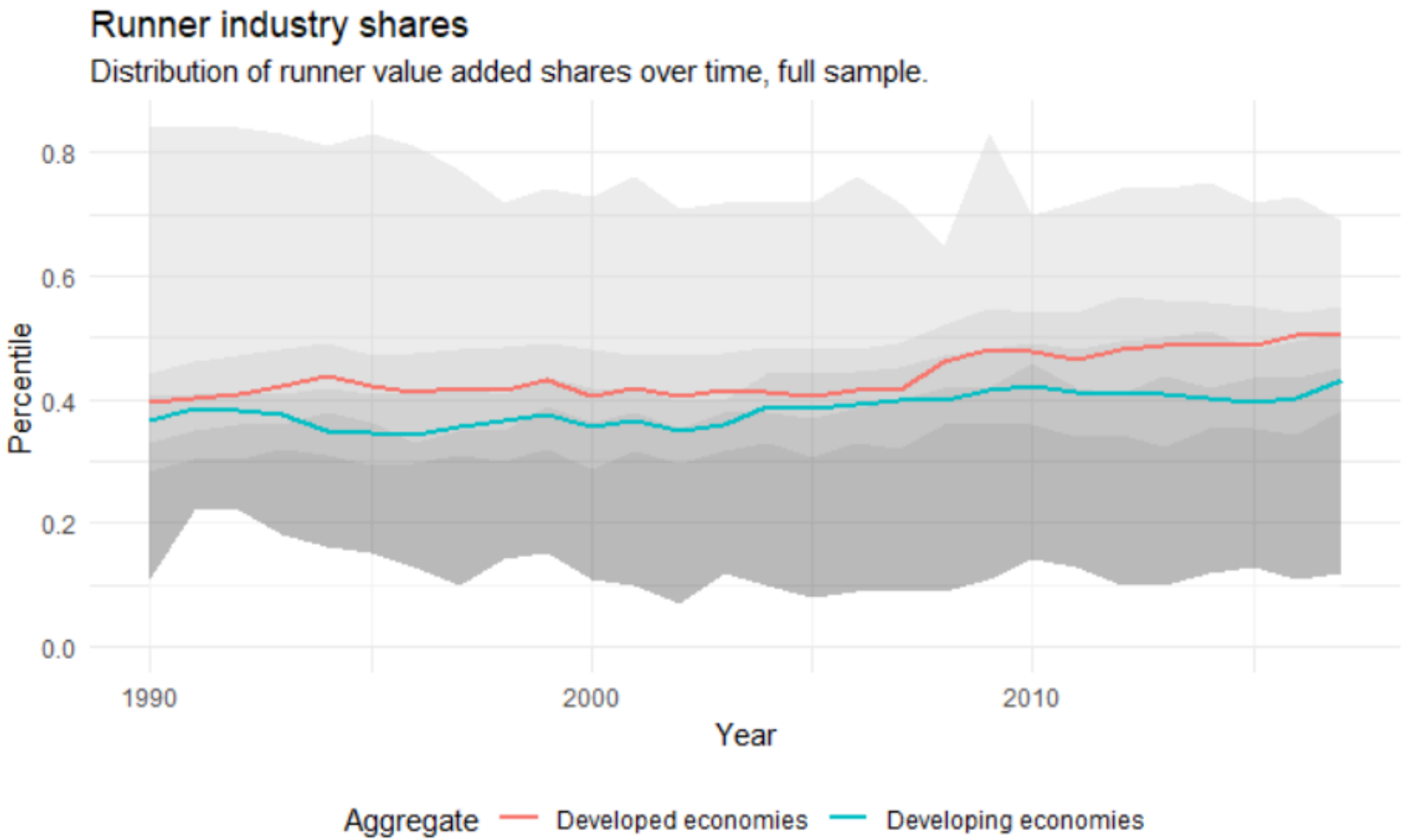
Classification

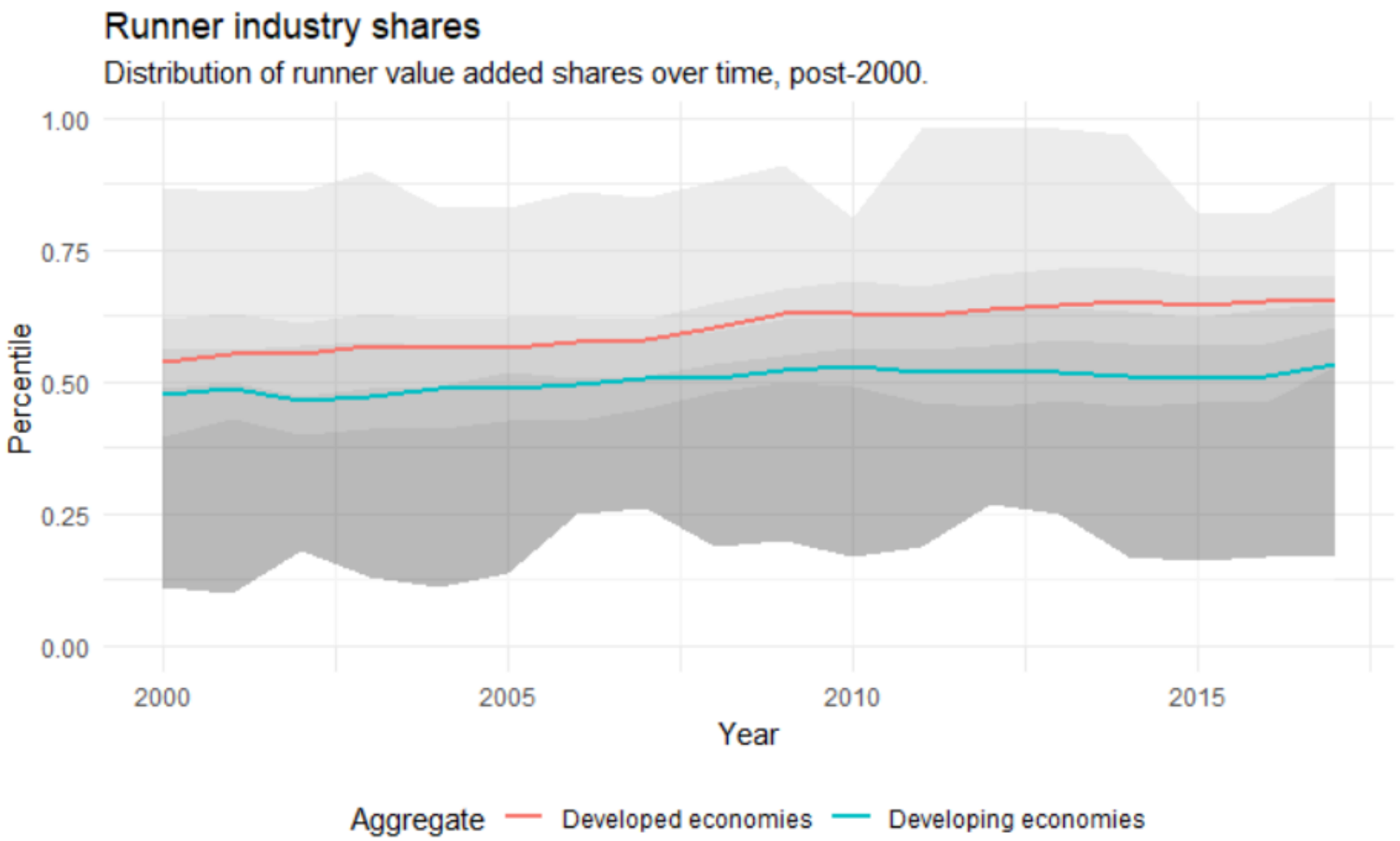
Industry 4.0 goods cluster	HS 2002 capital goods classification
Additive Manufacturing	847710 ("Injection-moulding machines");
	847720 ("Extruders");
	847730 ("Blow moulding machines");
	847740 ("Vacuum moulding machines and other thermoforming machines");
	847751 ("Other machinery for moulding or otherwise forming: For moulding or rethreading pneumatic tires or for moulding or otherwise forming inner tubes");
	847759 ("Other machinery for moulding or otherwise forming"); and
	847790 ("Parts").
CAD-CAM	845811 ("Horizontal lathes: Numerically controlled");
	845819 ("Other lathes: Numerically controlled");
	845921 ("Other drilling machines: Numerically controlled");
	845931 ("Other boring-milling machines: Numerically controlled");
	845951 ("Milling machines, knee-type: Numerically controlled");
	845961 ("Other milling machines: Numerically controlled");
	846011 ("Flat-surface grinding machines, in which the positioning in any one axis can be set up to an accuracy of at least 0.01 mm: Numerically controlled");
	846021 ("Other grinding machines, in which the positioning in any one axis can be set up to an accuracy of at least 0.01 mm: Numerically controlled");
	846031 ("Sharpening (tool or cutter grinding) machines: Numerically controlled");
	846221 ("Bending, folding, straightening or flattening machines (including presses): Numerically controlled");
	846231 ("Shearing machines (including presses), other than combined punching and shearing machines: Numerically controlled");
	846241 ("Punching or notching machines (including presses), including combined punching and shearing machines: Numerically controlled").
Robotics	847950 ("Industrial robots, not elsewhere specified or included")

Appendix: Runner Industry Decomposition

Rank (of 57)	Country	Runner value added share	Runner employment share	Income group
1	Switzerland	0.89	0.82	High-income
2	Luxembourg	0.87	0.90	High-income
4	Germany	0.80	0.79	High-income
6	France	0.79	0.79	High-income
7	Philippines	0.78	0.66	Lower middle-income
8	Hungary	0.77	0.74	High-income
9	Netherlands	0.76	0.77	High-income
12	Colombia	0.74	0.63	Upper middle-income
13	Croatia	0.74	0.65	High-income
20	Egypt	0.69	0.53	Lower middle-income
21	Indonesia	0.69	0.48	Lower middle-income
32	Ukraine	0.64	0.62	Lower middle-income
35	Bulgaria	0.62	0.57	Upper middle-income
40	Republic of Moldova	0.58	0.57	Lower middle-income
42	Viet Nam	0.54	0.33	Lower middle-income
44	Mongolia	0.51	0.42	Lower middle-income
46	Sri Lanka	0.50	0.36	Lower middle-income
47	India	0.47	0.50	Lower middle-income
57	Kyrgyzstan	0.17	0.50	Lower middle-income

Note:
INDSTAT 2 rev.3, 2000-2017, runner exposure shares shown for 2016. Ranking based on a total of 57 countries


Runner industry shares
Distribution of runner value added shares over time, full sample.
Percentile
0.8
0.6
0.4
0.2
0.0
1990
2000
2010
Year
Aggregate
Developed economies
Developing economies


Runner industry shares
Distribution of runner value added shares over time, post-2000.
1.00
0.75
0.50
0.25
0.00
Percentile
2000
2005
2010
2015
Year
Aggregate
Developed economies
Developing economies

Manufacturing Industries	High-income runner, full sample	High-income runner, post-2000	Upper middle-income group runners, full sample	Upper middle-income group runners, post-2000	Lower income group runners, full sample	Lower income group runners, post-2000	Global runners, full sample	Global runners, post-2000
15: Food and beverages			Yes	Yes		Yes	Yes	Yes
16: Tobacco								
17: Textiles								
18A: Wearing apparel								
20: Wood products			Yes	Yes				
21: Paper			Yes	Yes				
22: Printing and publishing			Yes					
23: Coke and refined petroleum								
24: Chemicals			Yes	Yes	Yes	Yes		Yes
25: Rubber and plastic	Yes		Yes	Yes			Yes	Yes
26: Minerals				Yes				
27: Basic metals								
28: Fabricated metals	Yes		Yes	Yes	Yes	Yes	Yes	Yes
29C: Machinery			Yes	Yes				
31A: Electrical machinery					Yes	Yes	Yes	Yes
33: Precision instruments	Yes		Yes	Yes				Yes
34A: Motor vehicles			Yes	Yes	Yes	Yes	Yes	Yes
36: Furniture, n.e.c					Yes	Yes		

Note: INDSTAT 2 rev.3.

To this end, Table C.3 summarizes the number of countries that reported positive productivity, value added as well as employment growth rates.