UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Inclusive and Sustainable Industrial Development Working Paper Series

WP 4 | 2021

Energy Prices and Firms' Economic Performance in Emerging Countries

DEPARTMENT OF POLICY, RESEARCH AND STATISTICS

WORKING PAPER 4/2021

Energy prices and firms' economic performance in emerging countries

Massimiliano Calì
World Bank

Nicola Cantore
UNIDO

Giovanni Marin
University of Urbino Carlo Bo; SEEDS

Massimiliano Mazzanti
University of Ferrara; SEEDS

Francesco Nicolli
University of Ferrara; SEEDS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Vienna, 2021

Table of Contents

List of Tables

List of Figures

Abstract

The relationship between energy price dynamics and competitiveness is crucial in the transition to environmental and economic sustainability. On the one hand, rising energy prices may induce process innovations and increase mark ups, thereby intensifying competitiveness. On the other hand, higher prices are expected to reduce competitiveness, because firms bear short-run costs that can partially be transferred to consumers. Emerging economies, where sectors and firms are less mature and more vulnerable to external shocks, require special attention in light of global development challenges. This paper evaluates the direct and indirect impact of energy prices on firms' economic performance for 11 developing countries over the period 2002–2013. The empirical analysis reveals that higher energy prices generally do not harm economic performance and may actually reinforce it in some cases. The scope and direction of this effect, however, depends on the firm's energy intensity.

Keywords: energy prices, economic performance, firms, energy intensity, competitiveness

JEL: Q52, Q48, H23, D22

1 Introduction

The impact of increasing energy prices on firm competitiveness has received growing attention in academic and policy debates in recent years. The issue became particularly relevant as economic instruments in the form of environmental and energy taxes ended up being incorporated into the price paid by firms to purchase and use energy inputs. On the one hand, environmental and energy taxes contribute to the internalization of a negative externality, generating valuable benefits for society as a whole. On the other hand, such economic instruments typically increase the price of non-renewable energy, which continues to be a key input to production in crucial sectors (e.g. iron and steel, non-metallic minerals, etc.), especially in emerging and developing countries. Environmental tax reforms that recycle the tax revenues back into firms or society may mitigate firms' and sectors' short-term costs and provide the basis for long-term net benefits (Ekins and Speck, 1999; EEA, 2016).

As formalized by Rentschler and Kornejew (2016), the literature identifies four principal strategies that firms can follow to cope with increasing energy prices. First, firms may be induced to adopt new and more efficient technologies that could reduce energy use. This 'innovation offset' effect is related to the Porter hypothesis (Porter and van der Linde, 1995),[1] and is expected to have a positive impact on overall business performance (Costantini and Mazzanti, 2012). Among the studies that support the presence of this effect, De Groot et al. (2001) find that Dutch firms tended to perceive such government interventions as a way to safeguard and sustain their competitive position, and consequently integrated the adoption of energy saving technologies as a 'normal' part of their business. Popp (2002) uses U.S. patent data to estimate the effect of an increase in energy prices on energy efficiency innovation between 1970 and 1994. He determines that energy prices had a strong and significant effect on the development of energy saving technologies. Aghion et al.'s study (2016) of the automotive sector suggests that firms' green innovation is triggered by increases in fuel prices, while brown innovation stalls. The stream of literature that focuses on the sectoral effects of environmental and energy regulations on energy-related technologies (Costantini et al. 2017; Costantini and Crespi, 2008 among others), with a focus on dynamic efficiency (Del Rio, 2008), is also worth noting. Finally, recent research using plant-level data from Indonesia and Mexico find that process innovation is a key channel for explaining the positive impact of energy prices on performance (Calì et al., 2019).

Second, higher energy prices can reduce competitiveness, if firms absorb the short-run costs without generating innovation offsets (a mechanism called *income effect* as highlighted in Kilian,

[1] See Barbieri et al. (2016) and Cohen and Tubb (2018) for a survey and meta-analysis, respectively.

2008). Marin and Vona (2021), for example, investigate how energy prices affected French manufacturing establishments between 1997 and 2015. They find that there is a trade-off between firms' environmental and economic objectives. Specifically, they estimate that a 10 per cent increase in energy prices leads to a reduction in CO_2 emissions of 11.5 per cent; however, at the same time, it also leads to a decrease in employment of -0.8 per cent and in firms' total factor productivity of -1.7 per cent. Other studies identify a possible increase of competitiveness over long-run dynamics (Costantini and Mazzanti, 2012).

Third, firms can partially transfer this increase in prices to consumers, thus reducing aggregate market demand. Ganapati et al. (2017) find that much of the energy price increases a sample of U.S. firms faced was ultimately borne by the final consumer. Their findings further show that for every dollar increase in the cost of energy, there was a USD 0.70 increase in the price of the final product. Sadath and Acharya (2015) evaluate how price variation affected the investment decisions of a sample of 6,806 manufacturing firms in India between 1993 and 2003. Their findings suggest that greater energy prices caused a decline in the firms' investment expenditure because of an income effect (i.e. the pass-through of increased costs to consumers generates a decrease in final output demand), and the inability to adequately cope with the increased marginal cost of production. It is clear that market structure, demand elasticity and the evolution of market willingness to pay are important factors to consider with regard to energy price increases.

Fourth, firms can switch to other sources of energy, if such sources are not taxed equally or if tax reforms change the relative costs of energy. Rentschler and Kornejew (2017) find that firms in Indonesia responded to an increase in certain energy prices by replacing more expensive energy sources with cheaper ones. Kerosene, and to a lesser extent diesel, are a viable substitute for all other energy sources, while LPG and petrol are the strongest complements. The authors also, however, show that firms adopted a mix of the four response measures summarized above to mitigate the adverse effects of higher energy prices. The prevalence of one channel over the others depends on firm- and sector-specific characteristics.

Moreover, the literature highlights that energy-intensive sectors are more likely to be affected by rising energy prices. Marin and Vona (2021), for instance, conclude that the magnitude of the negative effect of energy prices on firms' level of employment and productivity is higher in more energy-intensive sectors. A similar result is found in Sadath and Acharya (2015). By contrast, Goldar (2011), who assesses Indian firms' energy intensity performance between 1992 and 2007, finds a negative correlation between energy intensity and the price of electricity and coal, concluding that companies that face increased energy prices tend to be more energy efficient, with a positive impact on performance.

Finally, a last strand of literature suggests that several firm- and regional-level factors may influence the relationship between rising energy prices and firm performance. De Groot et al. (2001), for example, observe that firms' specific factors, such as the existence of more promising opportunities for investment (with respect to energy savings) and the incomplete depreciation of their previous investments are the main barriers to energy efficiency investments. Bernstein and Griffin (2006) show how state and sub-state differences influence the relationship between energy price and demand in the U.S. Abeberese (2017) and Dollar et al. (2005) suggest that the management of energy infrastructure and power outages in the developing world are possible sources of intra-regional differences when reviewing the effect of energy prices on firm performance.

Against this background, this paper aims to expand the empirical evidence on the effect of energy prices on firm competitiveness by focusing on middle- and upper-middle income countries. We focus, in particular, on three of the above-mentioned channels: the "energy efficiency" effect, the "absorption" effect, and the "pass-on" effect, and assess the extent to which the impact of energy price changes depends on the energy intensity of production. Finally, we also control for the potentially mediating role of several firm characteristics, which might play a relevant role in determining the effect of energy prices on economic performance. To do so, we exploit several firm-level panel datasets from the World Bank's Enterprise Survey (WB-ES), and the index for energy price at the sector/country/year level estimated by Sato et al. (2019). We obtained an unbalanced panel of firms in 11 countries observed over four years.

This paper enriches the existing literature across several dimensions. Firstly, it is the first contribution on the effect of energy prices on firm competitiveness to exploit microdata for multiple countries, as the majority of studies focus on single country data only. Secondly, several emerging countries are included in the study, allowing us to enlarge the scope of the analysis beyond the usual set of developed countries and to account for several possible different channels through which this mechanism might manifest itself. Thirdly, we investigate how interactions among different firm- and sector-specific factors influence firms' responses to changing energy prices.

This paper is related to the OECD's analysis of policies, eco-innovation and economic performance effects (Albrizio et al. 2017). It is also connected to the recent paper by Cantore et al. (2016), which uses World Bank data and shows that lower levels of energy intensity in developing countries are associated with higher total factor productivity (TFP), while higher energy efficiency is correlated with higher TFP at both the micro- and macro levels. Our work deepens the understanding of this mechanism at the micro level.

The paper is organized as follows: section two presents the methodology used to build our dataset and describes the econometric specification; section three presents the regression results and section four concludes.

2 Data and methodology

The empirical analysis draws on two data sources. The first is micro-level data from the World Bank's Enterprise Surveys (WB-ES). The dataset provides a detailed picture of a representative sample of firms in the formal sector, including information that ranges from firm characteristics such as number of employees, innovative activities, competitiveness, etc., to constraints to firms' performance and growth, e.g. infrastructure, crime, business-government relationship, etc. The data is particularly suitable for studying the relationship between energy prices and firm performance, given the repeated observations for the same firms over time. As explained in the following sections, tracking the same firms across several years allows us to carry out a robust econometric analysis that exploits the panel data structure.

The second source of information refers to our measure of energy prices. We use the energy price index estimated by Sato et al. (2019), which is available for the period 1995–2015 for 48 countries with a 12 sector breakdown. The country coverage of energy prices for less developed and emerging countries limits our analysis to 11 countries (Table 1) for which both firm panel data and sector-level energy price indices are available. Moreover, we focus on manufacturing and construction, which rely more directly on energy as a crucial input of production and for which we have detailed sector-level information on energy mixes.[2]

[2] We use the following harmonized sectoral breakdown: chemical and petrochemical; food and tobacco; iron, steel and non-ferrous metals; machinery; non-metallic minerals; textile and leather; transport equipment; construction.

Table 1 Countries included in the firm-level panel dataset[3]Table 1

Country	WB survey years (panel data)
Brazil	2003, 2009
Czech Republic	2002, 2005, 2009, 2013
Croatia	2002, 2005, 2009
Hungary	2002, 2005, 2009, 2013
Kazakhstan	2002, 2005, 2009
Mexico	2006, 2010
Poland	2002, 2005, 2009, 2013
Romania	2002, 2005, 2009
Russia	2005, 2009
Slovakia	2002, 2005, 2009, 2013
Turkey	2008, 2013

2.1 Measuring firm performance

We measure firms' growth and performance over time using standard indicators derived from the literature. In Table 2, we provide a list of these indicators and a detailed description of how they are built. The set of different indicators is used to test the three hypotheses outlined in section 1: (i) absorption, (ii) pass-on and (iii) energy efficiency.

Firm size is measured by exploiting the information on the firms' number of workers (*tot emp*). This can be used as a proxy to test the "absorption" hypothesis as outlined in section 1. The financial performance of firms is measured by using two standard productivity indicators. First, we employ sales per employee (*sales/emp)*, which can be used as a dependent variable to test the "pass-on" hypothesis; and secondly, value added per employee (*VA/emp*,) to test the "energy efficiency" (or Porter) hypothesis, which focuses on productivity.[4] Moreover, *return on sales* (*ROS*) measures firm profitability by dividing the firm's net income by its total sales, and can be used as an alternative dependent variable to test the "absorption" hypothesis. Net income is calculated by subtracting the cost of machinery, land, labour and intermediate goods from sales revenue. Finally, *export share* captures the percentage of products that firms export directly or sell to third parties that export products to other countries. This indicator is used as another proxy

[3] The size of the country pool depends on the energy related variable used in the estimation.
[4] We cannot employ measures of total factor productivity estimated as in Ackerberg et al. (2015) as the time dimension of our data is very small and information on fixed assets in WB Surveys is limited, thus leading to a very small number of selected non-missing observations.

to test the "absorption" hypothesis. The intuition is simple: in international markets, firms are often limited by an international price, and cannot pass extra costs to consumers.

2.2 Energy prices and intensity

The energy price index proposed by Sato et al. (2019) is calculated as the weighted average of country-year-specific prices for different energy sources (e.g. crude oil, natural gas, electricity, etc.) using country-sector-specific energy mixes as weights. Most of the data used by Sato et al. (2019) are drawn from the database of the International Energy Agency (IEA). Such an energy price index allows to account for energy price shifts common for all firms in the same country and in the same sector. The source of variation we exploit is the combination between the heterogeneity in the energy mix of each sector-country pair and changes in the national prices of different energy sources. Indeed, to increase the coverage in terms of countries and to limit endogeneity concerns (Marin and Vona, 2019; 2021), we Sato et al.'s (2019) version of the energy price index, which is based on a time-invariant (at the 1995 level) energy mix specific for each sector-country and on national time-varying shifts in the price of different energy sources. More formally, the index is computed as:

$$EP_{cst} = \log\left[\sum_j \theta_{jcs,1995} \times p_{jct}\right] \quad (1)$$

where $\theta_{jcs,1995}$ is the share of energy source *j* (e.g. crude oil, natural gas, electricity, etc.) over total energy use of sector *s* in country *c* in year 1995 and p_{jct} is the real price of energy source *j* in country *c* and year *t*.

Finally, to assess firms' exposure to energy prices, the energy intensity index is measured as fuel and electricity costs over revenue[5].

2.3 Econometric specification

We adopt the following benchmark specification to evaluate the impact of energy prices on firm performance:

$$Y_{it} = \pi_i + \beta EP_{cst} + \gamma EI_i \times EP_{cst} + \delta_c t + \phi_i^{foreign} t + \tau_t + \varepsilon_{it} \quad (2)$$

where Y_{it} represents a set of different measures of firm performance (see Table 2) for firm *i* and year *t*; π_i is the firm fixed effect to account for time-invariant firm-specific confounders; EP_{cst} is

[5] A usual indicator of energy intensity is represented by the ratio between a physical indicator of energy consumption and a monetary value of production. The World Bank Enterprise Survey does not contain information about consumption of energy, therefore, as in Cantore et al. (2016), we adopt a definition of energy intensity based on the monetary value of energy consumption and production.

the energy price index (in logarithm) for country c, sector s and year t; EI_i is the average (time-invariant) firm-level energy intensity measured as the ratio between energy expenditure (purchase of electricity and fuels) and sales,[6] $\delta_c t$ are country specific linear trends, $\phi_i^{foreign} t$ are trends specific for foreign-owned firms, and τ_t are time dummies. We explicitly account for different behaviours of foreign-owned companies, as managers of 'local' subsidiaries may have limited scope for developing independent strategies in response to changing energy prices. At the same time, however, depending on the country of origin of the group's headquarters, these companies may have better access to advanced technology to cope with increased energy costs.

Table 2 The dependent variables and their relationship to the research hypotheses

Variable name	Description	Measurement	Proxy used to test which channel
tot emp	Total number of employees in firm	l1 + l6	*Absorption*
sales/emp	Amount of sales over total employment	d2 / (l1+l6)	*Pass-on*
VA/emp	Value added over total number of employees	(d2-n2e)/(l1+l6)	*Energy efficiency*
Return on sales	Share of revenue converted into profit	(d2-n2e-n5a-n5b-n2a)/d2	*Absorption*
Export share	Percentage of exports	d3b + b3c	*Absorption*

Legend for the column Measurement:

WB Question #l1: Permanent, full-time employees end of last fiscal year (Number)

WB Question #l6: Full-time seasonal/temporary workers employed last fiscal year (Number)

WB Question #d2: What were this establishment's total annual sales?

WB Question #n2e: Total annual cost of raw materials and intermediate goods used in production (Number)

WB Question #d2: What were this establishment's total annual sales? (Number)

WB Question #n5a: How much did this establishment spend on purchases of machinery, vehicles and equipment (new or used)? (Number)

WB Question #n5b: How much did this establishment spend on purchases of land and buildings? (Number)

WB Question #n2a: Total annual cost of labour (including wages, salaries, bonuses, social security payments) (Number)

WB Question #d3b: What percentage of this establishment's sales were indirect exports (sold domestically to a third party that exports products)? (Share)

WB Question #d3c: What percentage of this establishment's sales were direct exports? (Share)

[6] We use average firm energy intensity (time-invariant) to limit endogeneity concerns related to the endogenous response of firms in terms of reduction in energy intensity as a consequence of higher energy prices.

It is worth noting that the empirical model includes interactions between energy intensity and changes in country-sector-specific energy prices. This allows us to test the heterogeneity of energy price effects across degrees of energy intensity, as we expect firms that rely more intensively on energy as an input to be more responsive to changing energy prices than firms with low energy intensity. β signifies the relationship between energy prices and firm performance for firms with zero energy intensity, while the net effect of energy prices on performance is denoted by $\beta + \gamma EI_i$. In particular, if β and γ are negative, a rise in energy prices has a stronger (negative) effect on the performance of more energy-intensive firms. We decided to use the time-invariant version of energy intensity as the interaction term to limit endogeneity concerns. The advantage of this approach is that—as highlighted by Marin and Vona (2021)—one typical source of endogeneity when accounting for the impact of energy price on firm performance is the fact that energy intensity and energy mix depend directly on energy prices. This comes at the cost of not being able to identify the direct effect of energy intensity on our outcome variable, as time-invariant variables are perfectly collinear with the firm fixed effect.

As EP varies over time as well as across both countries and sectors, we can identify the effects of price changes more precisely by also controlling for time-varying country-specific effects, thus accounting for other macro-trends such as GDP growth.

Firm fixed effects account for all unobserved time invariant differences across firms that may affect both energy prices and performance. These differences may refer, among other things, to managerial quality, business environment or geographical characteristics. However, to the extent that unobserved time-varying firm-level shocks might be correlated with both energy prices (or energy intensity) and firm performance (e.g. hiring a new manager), biased estimates of our parameters of interest would be generated. These concerns are minimized by using a time-invariant measure of energy intensity and by measuring sector-country level (rather than firm-level) energy prices.

2.4 Descriptive statistics

Figure 1 provides first insights into the relationship between energy prices and firms' performance and growth. We observe that the average value of performance indicators is more or less constant across quintiles of energy prices with the stark exception of exports, where we observe a positive relationship with energy prices (at the country-sector level). On the other hand, when we consider quintiles of (firm-level) energy intensity (in terms of energy costs per unit of sales), we observe a slightly negative relationship with productivity (in terms of both sales and value added) and profitability (ROS), while the relationship with export share is less clear.

Figure 1 **Firms' performance indicators over quintiles of the level of energy price index (x-axis; 1 low energy price index, 5 high energy price index)**

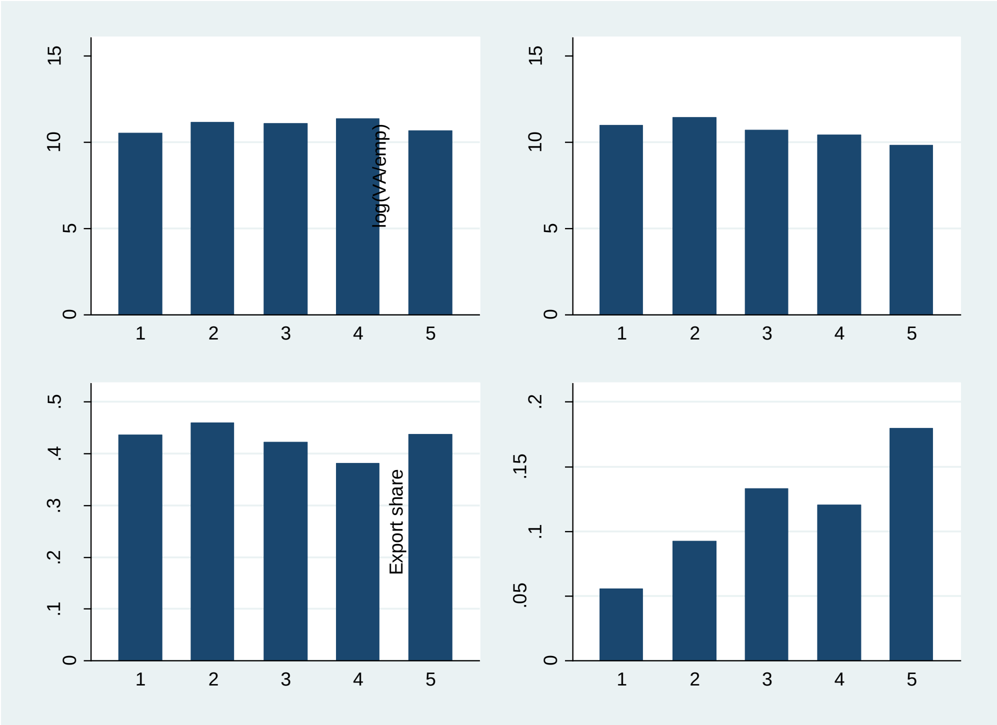

Figure 2 **Firms' performance indicators over quintiles of firms' energy intensity (x-axis; 1 low energy intensity, 5 high energy intensity)**

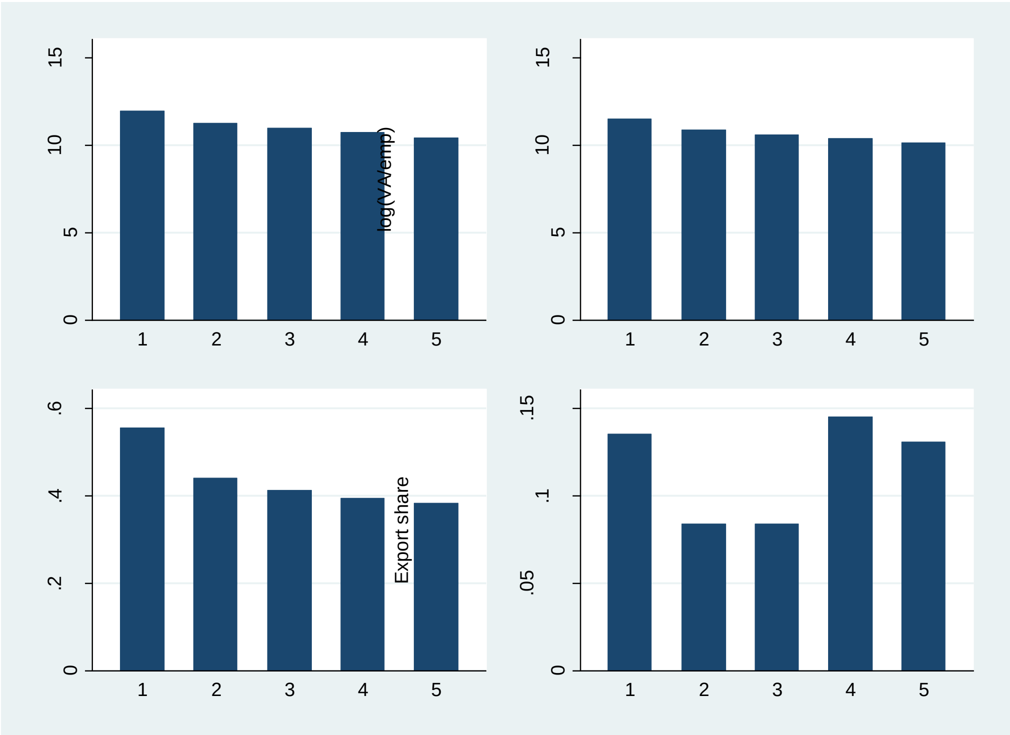

Table 3 presents the descriptive statistics of the dependent variables. It is worth noting that the data coverage varies substantially across dependent variables.

Table 3 Descriptive statistics: dependent variables

Variable	No.	Mean	SD	Min	Max
log(tot emp)	2,182	3.664	1.525	0	10.821
log(sales/emp)	1,767	11.011	2.036	-2.303	21.275
log(VA/emp)	1108	10.621	1.919	4.066	20.191
ROS (return on sales)	1,612	0.426	0.318	-0.98	1
Export share	2,188	0.115	0.255	0	1
Medium-big (dummy)	3,956	0.6269	0.4837	0	1
Domestic ownership (dummy)	3,956	0.8438	0.3631	0	1
Outages (dummy)	3,956	0.6302	0.4828	0	1
R&D (dummy)	3,956	0.1706	0.3762	0	1

3 Results

Coherently with the set of three hypotheses (*absorption, efficiency, pass-on*), we now turn to the results of various performance indicators: employment[7] (Column 1 of each table), productivity indicators (2 and 3), profitability indicators as return on sales (4), and competitiveness indicators, such as export (5). While Columns 2 and 3 refer, respectively, to the pass-on and efficiency hypotheses, 1, 4 and 5 refer to the absorption hypothesis.

Table 4 presents the main results of the baseline specification. While the direct effect of energy prices (i.e. the effect on firms with zero energy intensity) does not generally differ statistically from zero (except for ROS, with a positive effect, which is significant at 10 per cent), we observe a negative and significant interaction term for sales productivity (Col. 2), value-added based productivity (Col. 3) and ROS (Col. 4), with the effect being more precisely estimated in the latter two cases.

Contrasting results emerge for the absorption hypothesis, depending on the dependent variable used. Firm size, proxied here by total number of employees, is not influenced by energy prices, a result that is consistent across different levels of firms' energy intensity; likewise, export share is also not influenced by energy prices. It is worth noting that export performance depends on many

[7] See Horbach and Rammer (2019).

other market conditions (Antonietti and Marzucchi, 2014). As mentioned, energy prices exert an influence on ROS, which is conditional on the level of firms' energy intensity. This result is depicted in the lower part of Table 4, which reports the net effect of energy prices for selected values of energy intensity: the 10^{th} percentile, the median level and the 90^{th} percentile. In the case of ROS, the effect shrinks in size for rising EI level, but always remains positive, also at the 90^{th} percentile. Interestingly, the net effect is significant and positive only when EI is low, as shown by the 10^{th} percentile.

Regarding the other two hypotheses, our estimates reject both the 'pass-on' and 'efficiency/productivity' mechanisms (Columns 2 and 3). Nevertheless, the interaction term in both cases supports the argument that a rise in energy prices has a differential negative impact on energy-intensive firms. Finally, the net effect of energy prices on performance—presented in the last three rows of Table 4—reveals that the effect reverses and becomes negative above the 90^{th} percentile of EI distribution, but is never statistically significant.

Table 4 Baseline estimates

	(1)	(2)	(3)	(4)	(5)
	log(tot emp)	log(sales/emp)	log(VA/emp)	Return on sales	Export share
log(ener price)	0.00508	0.673	1.106	0.185*	0.0649
	(0.207)	(0.434)	(0.709)	(0.106)	(0.0459)
log(ener price) x energy exp share	-1.753	-12.93*	-20.12**	-1.540**	-0.776
	(1.533)	(7.298)	(9.435)	(0.745)	(0.473)
R sq	0.0651	0.177	0.135	0.326	0.0384
N	2182	1767	1108	1612	2188
Net effect: 10th percentile of EI	-0.00357	0.595	0.963	0.174*	0.0612
	(0.205)	(0.400)	(0.668)	(0.102)	(0.045)
Net effect: median of EI	-0.0405	0.333	0.569	0.144	0.0449
	(0.198)	(0.307)	(0.579)	(0.094)	(0.041)
Net effect: 90th percentile of EI	-0.168	-0.540	-0.767	0.0415	-0.0119
	(0.216)	(0.437)	(0.684)	(0.081)	(0.047)

Fixed effect estimator. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional controls: year dummies, country-specific linear trends, year-specific dummy for foreign owned firms

The overall message that can be derived from Table 4 is that higher energy prices do not generally hamper performance. If some positive effects do exist, they refer only to the profitability of firms with low energy intensity; neither efficiency-driven productivity gains and/or value effects through transferred energy costs (pass-on) seem to be positively affected. Though more energy-intensive firms evidently are affected relatively more by higher energy prices, looking at net effects, energy prices do not hamper economic performance, demonstrating that some compensatory offsets exist on innovation and market strategy. This is a positive message with respect to concerns that a reduction of fossil fuel subsidies or environmental taxation reforms revolving around carbon pricing may hamper firm competitiveness.

On the other hand, the lack of statistical significance of the impact of prices on the value added/employment ratio smooths the argument that process innovation or input substitution effects induced by higher energy prices may even have a positive effect on performance. In the observed countries, the weak and strong Porter-like effects actually seem absent. This is in line with the framework of the environmental Kuznets curve (Dinda, 2004), which suggests that technological efficiency gains are likely to arise only after a certain income threshold has been reached and the demand for basic needs is satisfied. This is unlikely to have fully materialized in the sample of countries selected for this study.

Further evidence is conveyed by exploiting the firm-specific features that are available in the World Bank questionnaire. Tables 5-8 present the heterogeneity of the effects of energy prices on performance, on the basis of firms' size (dummy equal to 1 for firms with 20 or more employees, Table 5), ownership (domestic vs foreign, Table 6), stability of energy supply (whether the firm experienced outages in the supply of electricity or not, Table 7) and innovativeness (whether the firm performed research and development (R&D) or not, Table 8). This is done by means of a series of interaction terms between the firm-specific characteristics and energy prices alone and the interaction of energy price-energy intensity, respectively.

Table 5 tests whether and to what extent the effect of energy prices and its interaction with energy intensity differ between medium and large firms (i.e. firms with 20 or more employees, which represent 64.6 per cent of the sample) and the total sample analysed in Table 4. The positive direct effect of energy prices on 'return on sales' is confirmed, as is the lack of statistical significance of other direct effects. Some interesting results emerge from analysing the net effects in the last two lines of the table. In three cases (*sales/emp*, *VA/emp* and *export share*) there is a positive and significant difference in the effect of energy prices between the full sample and medium and large

Table 5 Differential effect for medium-large firms (size effect)

	(1)	(2)	(3)	(4)	(5)
	log(tot emp)	log(sales/emp)	log(VA/emp)	Return on sales	Export share
log(ener price)	0.290	0.105	-0.171	0.361***	-0.0482
	(0.308)	(0.477)	(1.280)	(0.102)	(0.0533)
log(ener price) x Medium-large firm	-0.435	0.836	1.531	-0.260***	0.173***
	(0.296)	(0.554)	(1.046)	(0.0929)	(0.0535)
log(ener price) x energy exp share	-3.574	-5.137	-7.220	-2.271**	0.243
	(3.148)	(6.975)	(23.42)	(1.108)	(0.584)
log(ener price) x energy exp share x	2.726	-11.66	-14.20	1.009	-1.579**
Medium-large firm	(3.502)	(9.097)	(21.81)	(1.541)	(0.784)
R sq	0.0673	0.180	0.138	0.329	0.0457
N	2182	1767	1108	1612	2188
Net effect of log(ener price)	-0.145	0.940*	1.359*	0.100	0.124***
for medium-large firms	(0.213)	(0.498)	(0.816)	(0.113)	(0.0461)
Net effect of interaction	-0.849	-16.80*	-21.42**	-1.262	-1.336**
for medium-large firms	(1.274)	(8.647)	(9.31)	(1.013)	(0.556)

Fixed effect estimator. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional controls: country-specific linear trends, year-specific dummy for foreign owned firms

firms (the effect being greater in the latter case). Similarly, the difference in the interaction effect *energy prices * energy intensity* is significant and negative in the same three cases, signifying that energy-intensive medium and large firms have a less positive impact on performance variables from a rise in energy prices relative to other medium and large firms.

The overall message is that the set of hypotheses is not rejected when narrowing down the lens to more structured larger firms; innovation-related transmission channels originating from energy incentives might be at play. Porter-like mechanisms seem to exist but are linked to large and export-oriented agents, a result that is coherent with the Porter narrative (Costantini and Mazzanti, 2012).

Table 6 assesses the set of hypotheses with respect to domestically owned companies (87 per cent of the sample). There is a lack of evidence in relation to the main hypotheses: the direct energy price effect and the net effect of energy prices for domestically owned firms are not statistically significant. It remains true that the energy price-energy intensity joint effect undermines firms' economic performance as highlighted above, and accentuates that domestically owned firms are more vulnerable to increases in energy prices.

When interacting energy prices with a variable identifying companies that experience outages in energy supply (68 per cent of the sample, Table 7), we find a significant and positive net effect for two hypotheses: pass-on and absorptive, namely return on sales and export shares. This result shows that energy constraints associated with higher prices and other energy features can stimulate economic and innovation strategies to offset increasing energy costs.

Finally, as regards the niche share of firms engaged in R&D (12 per cent, Table 8), the results are mixed. Innovation factors change the picture when compared to the structural factors presented in Tables 5–7. Across the firms' performances, the direct energy price effect is positive in three cases, with a resulting net effect that is, nevertheless, either not significant or negative in one case. Innovation strategies are important but have thus far not compensated the entire energy effect on performance. It is worth noting that even if the general evidence of the 'energy price-energy intensity' effect is negative, the effect is significant and positive in one case (productivity, Porter hypothesis). This is the only such case across all specifications. It may suggest that investing in R&D is a key channel for activating compensatory mechanisms that are able to offset the costs associated with energy prices and energy intensity.

Table 6 Differential effect for domestically owned companies

	(1)	(2)	(3)	(4)	(5)
	log(tot emp)	log(sales/emp)	log(VA/emp)	Return on sales	Export share
log(ener price)	-0.177	0.496	0.692	0.237	0.0197
	(0.427)	(0.790)	(1.076)	(0.168)	(0.0984)
log(ener price) x Dom ownership	0.218	0.215	0.136	-0.0638	0.0542
	(0.484)	(0.907)	(1.297)	(0.211)	(0.0983)
log(ener price) x energy exp share	0.335	4.281	23.15	0.406	1.959***
	(3.942)	(13.39)	(13.89)	(1.967)	(0.667)
log(ener price) x energy exp share x	-2.471	-20.63	-44.87***	-2.344	-3.192***
Dom ownership	(4.142)	(15.86)	(13.71)	(2.177)	(0.791)
R sq	0.0654	0.183	0.146	0.327	0.0477
N	2182	1767	1108	1612	2188
Net effect of log(ener price)	0.0409	0.711	0.829	0.173	0.0739
for domestically owned firms	(0.229)	(0.492)	(0.777)	(0.127)	(0.045)
Net effect of interaction	-2.136	-16.35*	-21.72**	-1.938**	-1.234***
for domestically owned firms	(1.554)	(8.503)	(9.546)	(0.865)	(0.427)

Fixed effect estimator. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional controls: country-specific linear trends, year-specific dummy for foreign owned firms

Table 7 Differential effect for companies experiencing outages in the supply of energy

	(1)	(2)	(3)	(4)	(5)
	log(tot emp)	log(sales/emp)	log(VA/emp)	Return on sales	Export share
log(ener price)	0.117	0.700	1.736	0.122	0.00888
	(0.364)	(0.638)	(1.094)	(0.140)	(0.0388)
log(ener price) x Outage (dummy)	-0.151	-0.0286	-0.843	0.0871	0.0774
	(0.259)	(0.313)	(0.703)	(0.180)	(0.0449)
log(ener price) x energy exp share	-3.680	-7.417	-22.63	-0.465	-0.346
	(5.305)	(13.19)	(20.22)	(1.420)	(0.330)
log(ener price) x energy exp share x	2.690	-8.380	3.189	-1.575	-0.577
Outage (dummy)	(5.290)	(9.181)	(13.93)	(1.979)	(0.868)
R sq	0.0656	0.179	0.137	0.326	0.0397
N	2182	1767	1108	1612	2188
Net effect of log(ener price)	-0.0348	0.672	0.893	0.209**	0.0863*
for firms with outages	(0.180)	(0.565)	(0.874)	(0.096)	(0.047)
Net effect of interaction	-0.989	-15.80	-19.44	-2.040**	-0.922
for firms with outages	(1.032)	(11.640)	(14.790)	(0.990)	(0.722)

Fixed effect estimator. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional controls: country-specific linear trends, year-specific dummy for foreign owned firms

Table 8 Differential effect for companies engaged in R&D

	(1) log(tot emp)	(2) log(sales/emp)	(3) log(VA/emp)	(4) Return on sales	(5) Export share
log(ener price)	0.0659	0.860*	1.430**	0.221*	0.0532
	(0.212)	(0.457)	(0.646)	(0.114)	(0.0455)
log(ener price) x R&D dummy	-0.430	-1.231**	-3.060***	-0.249*	0.0757
	(0.348)	(0.611)	(0.757)	(0.134)	(0.0828)
log(ener price) x energy exp share	-2.354	-17.63**	-32.61***	-1.131	-0.304
	(1.868)	(8.395)	(7.060)	(0.835)	(0.435)
log(ener price) x energy exp share x	3.254	21.94**	40.78***	-1.510	-2.166***
R&D dummy	(2.681)	(8.630)	(7.955)	(0.946)	(0.543)
R sq	0.0663	0.184	0.162	0.330	0.0437
N	2182	1767	1108	1612	2188
Net effect of log(ener price)	-0.364	-0.372	-1.630*	-0.0280	0.129
for firms that engage in R&D	(0.354)	(0.504)	(0.832)	(0.130)	(0.083)
Net effect of interaction	0.901	4.312**	8.162**	-2.641***	-2.469***
for firms that engage in R&D	(1.636)	(2.124)	(3.478)	(0.702)	(0.443)

Fixed effect estimator. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional controls: country-specific linear trends, year-specific dummy for foreign owned firms

4 Conclusion and policy implications

This paper analyses the relationship between energy price dynamics and competitiveness in a panel data framework, with a detailed focus on firms' economic performance. Its originality lies in its two-dimensional analysis: first, the dynamic lens (Del Rio, 2008), as the paper evaluates the direct and indirect influence of energy prices on several measures of firms' economic performance for a panel of 11 countries over the period 2002–2013. Second, the effects on firm performance is tested by using sector/country level energy prices across 12 sectors. The use of original sector-specific data on energy prices combined with microdata in a panel setting adds value to the evidence in comparison with usual analyses based on country-level energy prices over more limited timespans.

Overall, the empirical analysis does not reject the hypothesis that higher energy prices, which may also potentially be influenced by energy policies, could even be positively related to better economic performance. On the other hand, energy intensity negatively influences performance, as may be expected, confirming the relevance of including various firm and sectoral features to better understand the magnitude of the core tested relationship (energy prices – economic performance).

The picture that emerges from the various analyses is as follows: when focusing on the total sample of firms, energy intensity tends to undermine performance: energy prices exert mechanisms to offset costs, but not to more than compensate the increasing energy costs. Even if the evidence is mixed, this is a first result that indicates that some channels through which energy prices may be correlated with enhanced economic performance are in place in emerging economies.

Looking at firm features in more detail, estimates show that the energy price-economic performance relationship can be positively oriented due to structural conditions (e.g. large firms size), and strategies that characterize a niche share of firms, such as engagement in formal R&D activity. Those outcomes are not new, but confirm that both structural features and endogenous growth-enhancing innovation investments help firms cope with energy issues. In addition, firms exposed to energy constraints, such as outages, appear to have reacted by introducing compensatory mechanisms and thus present positive net effects in relation to economic performance. The domestic nature of firms seems to be less relevant, which nevertheless is worth noting given their large share in the sample, and the hypothesis that domestic oriented governance may hamper global competitiveness and sustainability.

Overall, the evidence demonstrates that firms in emerging economies respond to energy price increases with diverse strategies: pass-on, increases in sales value by transferring energy costs to consumers; 'absorption' strategies, as well as measures that enhance productivity/efficiency along a 'Porter hypothesis narrative', the latter especially among large firms and firms engaged in R&D.

Concerning specific performances, the bulk of the evidence points to return on sales, productivity of labour and export share. The employment effect is generally neutral.

The results of our analyses strongly support a re-evaluation of the conventional wisdom that energy and environmental costs (possibly also due to green taxes) may harm competitiveness by increasing energy costs. If anything, our results suggest that energy price increases can have a net beneficial impact on firms' productivity, growth and, in certain cases, also their profitability.

Environmental taxes (or the reduction of environmentally harmful subsidies) have far-reaching economic benefits by reducing environmental externalities. The evidence on middle-income countries presented in this study suggests that environmental taxes can also foster firm-level efficiency gains by encouraging more efficient energy use and investment in more modern equipment.

Further investigations are necessary to deepen the analysis of the different effects of energy price changes and energy policies, and to enhance the breadth and quality of datasets on firms' innovations and performance. Attempts to merge firms' datasets with meso- and macro sources are encouraged as well.

References

Abeberese, A. B. (2017). Electricity Cost and Firm Performance: Evidence from India. *The Review of Economics and Statistics,* 99(5), 839–852.

Ackerberg, D. A., Caves, K., Frazer, G. (2015). Identification Properties of Recent Production Function Estimators. *Econometrica,* 83(6), 2411-2451.

Aghion, P., Dechezleprêtre, A., Hémous, D., Martin, R., Van Reenen, J. (2016). Carbon Taxes, Path Dependency, and Directed Technical Change: Evidence from the Auto Industry. *Journal of Political Economy*, 124(1), 1-51

Albrizio, S., Kozluk, T., Zipperer, V. (2017). Environmental policies and productivity growth: Evidence across industries and firms. *Journal of Environmental Economics and Management*, 81, 209-226.

Antonietti, R., Marzucchi, A. (2014). Green tangible investment strategies and export performance: A firm-level investigation. *Ecological Economics, 108,* 150–161.

Barbieri, N., Ghisetti, C., Gilli, M., Marin, G., Nicolli, F. (2016). A Survey of the Literature on Environmental Innovation Based on Main Path Analysis. *Journal of Economic Surveys,* 30(3), 596-623.

Cantore, N., Calì, M., te Velde, D.W. (2016). Does energy efficiency improve technological change and economic growth in developing countries? *Energy Policy*, 92, 279-285.

Cohen, M. A., Tubb, A. (2018). The Impact of Environmental Regulation on Firm and Country Competitiveness: A Meta-Analysis of the Porter Hypothesis. *Journal of the Association of Environmental and Resource Economists*, 5(2), 371-399.

Costantini, V., Mazzanti, M. (2012). On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports. *Research Policy*, 41(1), 132-153.

Costantini, V., Crespi, F. (2008). Environmental regulation and the export dynamics of energy technologies. *Ecological Economics*, 66(2-3), 447-460.

Costantini, V., Crespi, F., Palma, A. (2017). Characterizing the policy mix and its impact on eco-innovation: A patent analysis of energy-efficient technologies. *Research Policy*, 46(4), 799-819.

Del Rio, P. (2008), Assessing the dynamic efficiency of internal mitigation projects. An evolutionary perspective. *Mitigation and Adaptation Strategies for Global Change*, 14, 203-213.

Dethier, J., Hirn, M., Straub, S. (2011). Explaining enterprise performance in developing countries with business climate survey data. *World Bank Research Observer*, 26 (2), 258–309.

Dinda, S. (2004). Environmental Kuznets curve hypothesis: a survey. *Ecological Economics,* 49(4), 431-455.

Dollar, D., Hallward-Driemeier, M., Mengistae, T. (2005). Investment climate and firm performance in developing economies. *Economic Development and Cultural Change*, 54(1), 1–31.

EEA (2016), *Environmental Taxation and EU Environmental Policies*, Report 17, EEA, Copenhagen.

Ekins, P., Speck, S. (1999). Competitiveness and Exemptions From Environmental Taxes in Europe. *Environmental and Resource Economics*, 13(4), 369-396.

Ganapati, S., Shapiro, J. S., Walker, R. (2016). The incidence of carbon taxes in US manufacturing: Lessons from energy cost pass-through. National Bureau of Economic Research No. w22281.

Horbach, J., Rammer, C., (2019). Circular economy innovations, growth and employment at the firm level: Empirical evidence from Germany. *Journal of Industrial Ecology*, 24(3), 615-625.

Kilian, L. (2008). The economic effects of energy price shocks. *Journal of Economic Literature*, 46(4), 871–909.

Marin, G., Vona, F. (2019). Climate Policies and Skill-Biased Employment Dynamics: Evidence from EU countries. *Journal of Environmental Economics and Management*, 98, 102253.

Marin, G., Vona, F. (2021). The impact of energy prices on socioeconomic and environmental performance: Evidence from French manufacturing establishments, 1997–2015. *European Economic Review*, 135, 103739.

Popp, D. (2002). Induced Innovation and Energy Prices, *American Economic Review*, 92(1), 160-180.

Porter, M. E., van der Linde, C. (1995). Toward a New Conception of the Environment-Competitiveness Relationship. *Journal of Economic Perspectives*, 9(4), 97–118.

Rammer, C., Gottschalk, S., Peneder, M., Wörter, M., Stucki, T., Arvanitis, S. (2017). Does energy policy hurt international competitiveness of firms? A comparative study for Germany, Switzerland and Austria. *Energy Policy*, 109, 154–180.

Rentschler, J., Kornejew, M. (2017). Energy price variation and competitiveness: Firm level evidence from Indonesia. *Energy Economics*, 67, 242–254.

Sadath, A. C., Acharya, R. H. (2015). Effects of energy price rise on investment: Firm level evidence from Indian manufacturing sector. *Energy Economics*, 49, 516–522.

Sato, M., Singer, G., Dussaux, D., Lovo, S. (2019). International and sectoral variation in industrial energy prices 1995-2015. *Energy Economics*, 78, 235-258.

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Vienna International Centre · P.O. Box 300 9 · 1400 Vienna · Austria
Tel.: (+43-1) 26026-0 · E-mail: info@unido.org
www.unido.org