

Too Much Energy

The Perverse Effect of Low Fuel Prices on Firms*

Massimiliano Calì[†] Nicola Cantore[‡] Leonardo Iacovone[§]
Mariana Pereira-López[¶] Giorgio Presidente^{||}

Abstract

This paper provides novel evidence on the impact of changes in energy prices on manufacturing performance in two large developing economies - Indonesia and Mexico. It finds that unlike increases in electricity prices, which harm plants' performance, fuel price hikes result in higher productivity and profits of manufacturing plants. The results of instrumental variable estimation imply that a 10 percent increase in fuel prices would lead to a 1.6 percent increase in total factor productivity for Indonesian and 1.4 percent for Mexican plants. These effects are driven by the incentives that fuel price increases provide to plants towards replacing inefficient fuel-powered with more productive electricity-powered capital equipment. These results help to re-evaluate the policy trade-off between reducing carbon emissions and improving economic performance, particularly in countries with large fuel subsidies such as Indonesia and Mexico.

Keywords: Fuel subsidy, energy prices, productivity, technology adoption, Indonesia, Mexico. **JEL codes :** O13, Q4, Q55

*We thank Antoine Coste, Auфа Doarest, Ana Fernandes, Frederico Gil-Sander, Bill Maloney, Denis Medvedev, Vikram Nehru, Jun Rentschler and seminar participants at the GGKP Annual Conference and the World Bank Indonesia seminar series for useful comments, Taufik Hidayat, Muhammad Hazmi Ash Shidqi and Nabil Rizky Ryandiansyah for excellent research assistance and Julio Valle for his advisory on Mexico's Energy Sector. We also thank the editor and two anonymous referees for their helpful comments. All remaining errors are our own.

[†]World Bank, email: mcali@worldbank.org

[‡]UNIDO, email: n.cantore@unido.org

[§]World Bank, email: liacovone@worldbank.org

[¶]World Bank & Universidad Iberoamericana, email: mpereiralopez@worldbank.org

^{||}World Bank, email: giopresidente@gmail.com (Corresponding author)

1 Introduction

Curbing fossil fuel consumption is essential to keep global warming within levels that will still allow societies to function (Intergovernmental Panel on Climate Change, 2018). Yet, governments are reluctant to take significant measures to reduce emissions, including decisive taxes on carbon. This resistance is partly due to the concern that an increase in the price of energy could harm domestic producers by increasing the cost of a key production input (Rentschler et al., 2017). The argument is particularly salient in industrializing countries where governments often subsidize fuel consumption by keeping fuel prices below market prices.¹

This paper uses data from two large developing countries (Indonesia and Mexico) to provide novel evidence that increases in energy prices do not necessarily worsen the performance of manufacturing firms. These countries provide a suitable context for the analysis for three main reasons. First, energy prices in both countries are subject to frequent variations both across plants and over time, and such changes may be traced back to institutional and geographical factors exogenous to the plants. Second, unlike most other developing countries, Indonesia and Mexico collect rich panel data of manufacturing plants, which include critical information for the estimation. Third, the results of the analyses can inform the policy discussion on the phasing out of fuel subsidies in both countries, which is opposed also on the grounds of industrial competitiveness arguments.²

The key innovation of the analysis is testing for the impact of energy price variations separately for electricity and fuels, the two main types of energy used by manufacturing firms. This represents a departure from most of the literature on energy and plants' performance, which has tended to focus on electricity (e.g.

¹Coady et al. (2015) estimate that energy subsidies would account for between 13% and 18% of GDP in Developing and Emerging Asia, the Middle East, North Africa, and Pakistan (MENAP), and the Commonwealth of Independent States (CIS).

²In 2013-14 both countries set out to reverse years of sizable fossil fuel subsidies. The Mexican government proposed an ambitious carbon tax on fossil fuel consumption in 2013. However, during the approval process, industrial and social groups successfully lobbied the Mexican Congress to reduce the level of the proposed tax on the ground that it would harm the competitiveness of domestic industries and raise inflation (Arlinghaus and Van Dender, 2017). Similarly, the Indonesian government removed much of the long-standing fuel subsidy from the national budget in 2015. However concerns similar to those of the Mexican case eventually led the government to reinstate part of the subsidy.

Abeberese, 2017; Allcott et al., 2016; Fried and Lagakos, 2019; Marin and Vona, 2017).³

Distinguishing between energy sources is important as they power different types of capital equipment. For example, electric heating technologies are typically more energy-efficient and more productive than fuel-powered ones (EPRI, 2007). A case in point is the boiler, which is used to produce heat in virtually all manufacturing industries: fuel-powered boilers tend to be older, less energy-efficient and less productive than electricity-powered ones (Malek, 2005). This is also consistent with our data and case studies from the engineering literature. Additional examples of capital equipment used in manufacturing production that can be fueled by both fuel and electricity include industrial dryers, air compressors, rototillers, chainsaws, motors, ovens, excavators, etc. A recent report (McKinsey, 2020) show that almost 50% of industrial operations (from low temperature such as washing and food preparation to high temperature such as cracking in the petrochemical industry) present a financially viable switch from fuel to electricity.⁴ As a result, variations in relative prices could shape incentives to adopt different vintages of capital equipment.

As it turns out, the effects of price changes are markedly different between fuels and electricity. We find that increases in fuel prices result in higher productivity and profits among manufacturing plants. Our estimates imply that for Mexico, a 10% increase in fuel prices leads to an increase of 1.4% in Revenue Total Factor Productivity (TFPR) and a 14% in profits; for Indonesia, a 10% increase in fuel prices raises productivity by 1.6% and profits by 18%.

A battery of tests suggests that these effects are mainly driven by the replacement of older fuel-powered capital with more efficient and electricity-intensive capital in response to fuel price increases (keeping electricity prices constant). We find that in both countries higher fuel prices trigger the sale of machinery and the purchase of new equipment, and an increase in electricity consumption per unit of

³Rentschler and Kornejew (2018) is among the few studies considering the impact of a variety of energy sources on performance in a cross-sections of small and micro Indonesian manufacturing firms. Instead, this paper focuses on panels of medium and large plants, which crucially allows to control for plant-specific time invariant factors.

⁴Deloitte (2020) estimates that the year 2020 witnessed the highest rate of switch from fuel to electricity globally.

capital. While the switch towards electric machinery induced by fuel price hikes is to be expected, we also find that they result in higher quantity-TFP (TFPQ), a key measure of technical efficiency.⁵ Thus, we take the evidence as suggesting that higher fuel prices trigger technological upgrading among laggard plants. Consistently with this interpretation, we find that the positive impact of fuel prices on machinery turnover is muted for electricity-intensive plants - for which the scope for technological upgrading in response to fuel price is reduced - as well as for foreign plants, which are more likely to use technology closer to the frontier (Blackman and Wu, 1999; Guadalupe et al., 2012; Brucal et al., 2018).

Unlike for fuels, we do not find a positive impact of electricity prices on plants' performance. This result is consistent with the fact that electricity prices do not incentivize productivity-enhancing capital replacement, because electricity powers technologies that are already on the efficiency frontier. Hence plants have less room to improve the capital vintage as a result of electricity price movements. In the absence of the capital replacement channel, rising electricity prices turn out to have a negative impact on plants' performance and profitability, in line with previous literature (Abeberese, 2017; Marin and Vona, 2017).

One advantage of the Indonesian and Mexican manufacturing data is that they include detailed information on outputs and inputs for each plant over time. However only the Indonesian data includes value and quantity of energy consumed, which allows estimating plant-specific unit prices for electricity and fuels. The Mexican data includes only the total plant-level expenditures on electricity and on other fuels. To estimate plant-level energy prices, we combine various sources of data. For electricity we combine monthly data on regional electricity tariffs by firm size with plant-specific sales, electricity expenditures and monthly production; to construct fuel prices we match sector-specific fuels' consumption with monthly fuel price data and plant-specific monthly production data.

A challenge with these energy prices - particularly for Indonesia - is that they are endogenous with respect to plant-level outcomes. This problem is less severe for Mexico as the plant-level data are constructed using national, sectoral and regional

⁵The results of a placebo test provide further support to this hypothesis by showing that changes in fuel prices are instead not associated with other types of non production capital such as land and buildings.

data. To address these endogeneity concerns we instrument energy prices in both countries using energy prices of neighboring plants for Indonesia and, in the case of Mexico, average energy prices of plants from the same sector and state (excluding the firm analyzed in each case). Despite the spite of the differences in the data, the instrumental variables employed and in the structure of the two economies, the result that an increase in fuels prices boosts performance is remarkably robust across countries. This robustness relieves the concerns on the external validity of the results that typically affect single country empirical analyses.

To the best of our knowledge, this is the first paper providing systematic evidence on higher factor costs leading to a more productive use of resources and higher profitability. In the energy literature, such a possibility is known as the strong version of the Porter Hypothesis, which was theorized by Porter and Van der Linde (1995). In its strong version, the Porter Hypothesis states that stricter environmental policy can induce firms to invest in better technology that not only results in higher productivity, but also higher profits. The strong version of the Porter Hypothesis has not received empirical support to date.⁶

This lack of support is particularly salient given that the strong Porter hypothesis is at odds with standard classes of models with no market imperfections and profit-maximizing producers. Under those conditions, an increase in factor cost must necessarily lead to worse performance: if profitable opportunities existed before the price increase, rational producers would already be exploiting them. For instance, Xepapadeas and de Zeeuw (1999) present a model in which carbon taxes induce a modernization of the capital vintage and increase average productivity, but reduce profits.⁷

Instead, with market imperfections it is theoretically possible to have a positive link between factor prices and profits. For instance, within a standard model of directed technical change, Acemoglu (2010) shows that market power in the technology-producing sector can lead firms to chose not the profit-maximizing technology. In that model, the increase in price of a factor can induce adoption of

⁶Cantore et al. (2016) show that the trade-off between higher energy prices and performance might be softened by the positive relation between energy efficiency and productivity, but they do not study how energy prices affect technological choice.

⁷The theoretical model in Xepapadeas and de Zeeuw (1999) is consistent with empirical evidence in Popp (2002), where higher energy prices lead to adoption of energy-saving technology.

a technology which “saves” on that factor, ultimately resulting in higher profits.

A growing literature finds evidence of market imperfections and bounded rationality even in advanced economies, which help explain slow adoption of energy efficient technology even in the presence of positive net present value of the investment (McKinsey, 2009; Anderson and Newell, 2004; DeCanio and Watkins, 1998; DeCanio, 1993; Poterba and Summers, 1995). In addition, a number of case studies suggest that investment in technology undertaken with the primary objective of increasing energy-efficiency often provide surprisingly high productivity gains.⁸ Findings in Ryan (2018) and Bloom et al. (2013) suggest that the frictions responsible for sub-optimal investment decisions might be even more severe in less advanced countries.

The incentives to gather and process information about energy-efficient technological opportunities might be particularly low in countries such as Indonesia and Mexico, where heavily subsidized prices result in energy-efficiency being not a major concern for the average producer. Our finding that the positive impact of fuel prices on investment is muted for foreign and exporting plants provides further support to the market frictions and bounded rationality hypothesis, as information frictions and deviation from profit-maximizing behavior are likely to be more limited for these firms.

The rest of the paper is organized as follows. Section 2 discusses some of the key institutional features of the case studies; Section 3 describes data; Section 4 sets out the identification strategy; Section 5 provides the results, and Section 6 concludes.

2 Institutional context

Indonesia and Mexico are particularly suitable contexts to study the relation between fuel prices and firms’ performance. First, they are two of the largest emerging countries, which together account for 2.6% of world’s CO₂ emissions.⁹ A

⁸Pye and McKane (2000) document how energy efficiency projects increase shareholder value. Worrell et al. (2003) find that the majority of the case studies in manufacturing sectors across six OECD countries exhibited non-energy benefits of equal or greater size than the energy savings.

⁹The figure refers to 2014 according to World Bank Data on emissions.

significant part of the emissions is due to fuel consumption, which is sustained by long-standing policies of subsidized fuel prices in both countries, including for industrial users. These subsidies translate into some of the lowest fuel prices among a large sample of countries for which this data are available (panel a) in Figure 1).¹⁰

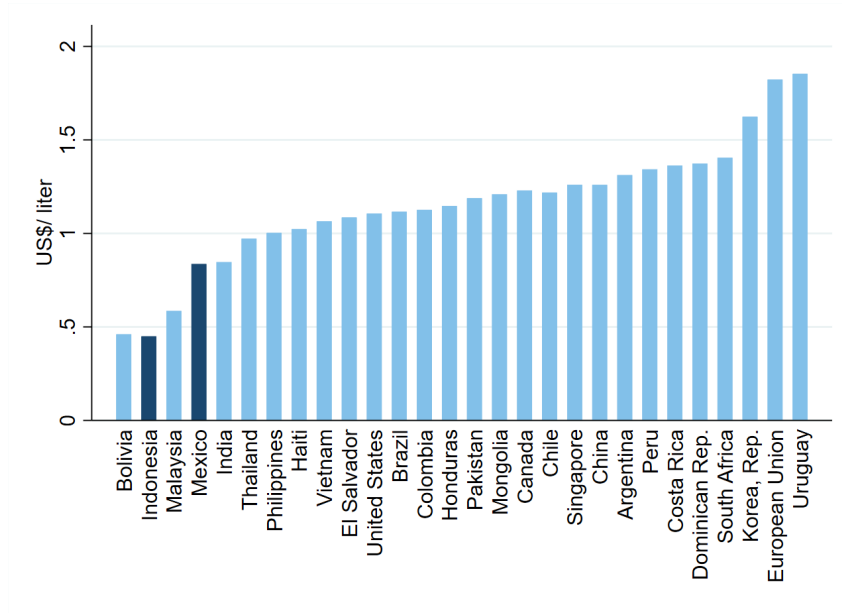
The low prices have contributed to relatively high consumption of fossil fuel by domestic industries in both countries. Fuels account for roughly 65% of total energy consumption in the average manufacturing plant in Indonesia and 68% in Mexico, but only 40% in France (Marin and Vona, 2017), where fuel prices are considerably higher in purchasing power parity terms. On the other hand electricity prices in both countries are in the middle range within the same sample of countries, and for example are higher than in France and several other OECD countries (panel b) in Figure 1).

These countries are also a suitable laboratory for our analysis given the relatively low dependence of their manufacturing plants on generators. This is an important pre-condition to test for the differential impact of fuel and electricity prices on performance as generators are powered by fuels to generate electricity. In the extreme case of a plant relying entirely on generators for electricity, a fuel price increase will proportionately affect its electricity price too, thus preventing the identification of the differential impact across energy sources. Less than 20 percent of manufacturing plants in the Indonesian sample used a generator at the beginning of the period of our analysis in 1999, a share that drops to 12 percent by the end of the period in 2015. Even among these plants, the majority spends more on grid electricity than on fuel for the generator. In Mexico, according to the recently published 2019 Economic Census, which is the first one that includes the value of generators as a separate category within fixed assets, only 1.4 percent of plants in the manufacturing sector report having generators.

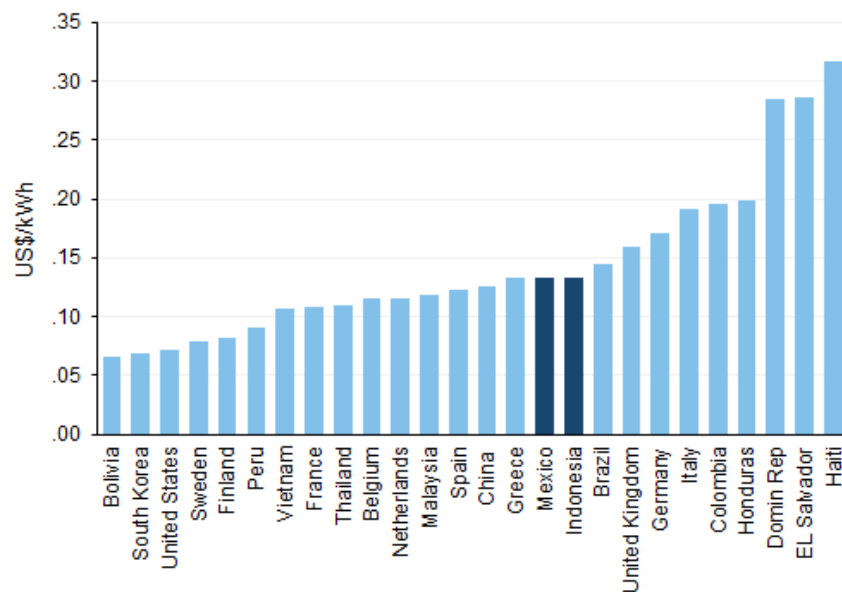
¹⁰In Indonesia the subsidy has been largely phased out in the public budget at the end of 2014, but energy prices continue to be implicitly subsidized by the state owned monopolists of electricity production and distribution and of fuels distribution, which also generates concerns for their economic sustainability. In 2014 the Mexican government has started implementing a gradual reform of the energy sector and it introduced a carbon tax, although the tax was limited in scope.

Figure 1: International comparison of Energy Prices

(a) Diesel prices



(b) Industrial electricity prices



Source: Beylis and Cunha (2017)

2.1 Indonesian energy markets

Indonesia has long followed a policy of government-mandated national level prices in both electricity and fuel markets. The prices of the main energy sources are set by the Ministry of Energy and Mineral Resources in accordance with the state-owned national monopolists Perusahaan Listrik Negara (PLN) and Pertamina. The former is responsible for the vast majority of production and distribution of electricity nationally. The electricity tariffs are set nationally for different groups of users, including industrial and residential users. The former are in turn divided into various categories according to the sector and the installed capacity. A further source of variation in tariff is the timing of the electricity consumption with discounts for use during times of low demand within the day. Pertamina is a quasi-monopolist in the distribution of diesel and gasoline, which are the major fuels used by manufacturing plants in production. It is also responsible for refining the domestically produced fuels.¹¹

Given these price setting mechanisms, prices are supposedly homogeneous across the country. In fact the highly heterogeneous geography characterizing Indonesia results in substantial heterogeneity in distribution costs across different provinces, and a multitude of major island or groups of Islands.¹² The large variation in energy distribution costs is well documented (IEA, 2015; Inchauste and Victor, 2017) and is confirmed in our data.

As shown in Figure 2, in real terms both electricity and fuel prices faced by manufacturing plants increased in a non-uniform way across the Indonesian archipelago in the period of analysis (1998-2015). The electricity price increase was particularly marked in central Kalimantan, in eastern Sumatra and Maluku. In these relatively remote regions, electricity supply often depends on local power generation capacity and off-grid solutions (Rentschler and Kornejew, 2018). The price increase was also relatively large in West Java, where the high density of plants poses challenges for electricity distribution to keep up with heavy demand.¹³ Fig-

¹¹Domestic refining covers just over 50 percent of the Indonesian gasoline and diesel markets

¹²While today Indonesia is divided into 33 provinces, we use the administrative division of provinces at the beginning of our period of analysis, when Indonesia was split into 27 provinces.

¹³This is also consistent with the 2009 World Bank Enterprise data, which shows that high shares of firms in West Java experienced power outages relatively to northern Sumatra.

ure A2 in the appendix (panel a) lends support to the idea that electricity prices increased more in provinces with a relatively poor quality of the grid. An inverse proxy for the latter is the province-level average self-generated electricity as a share of total electricity consumed over the entire period 1998-2015.

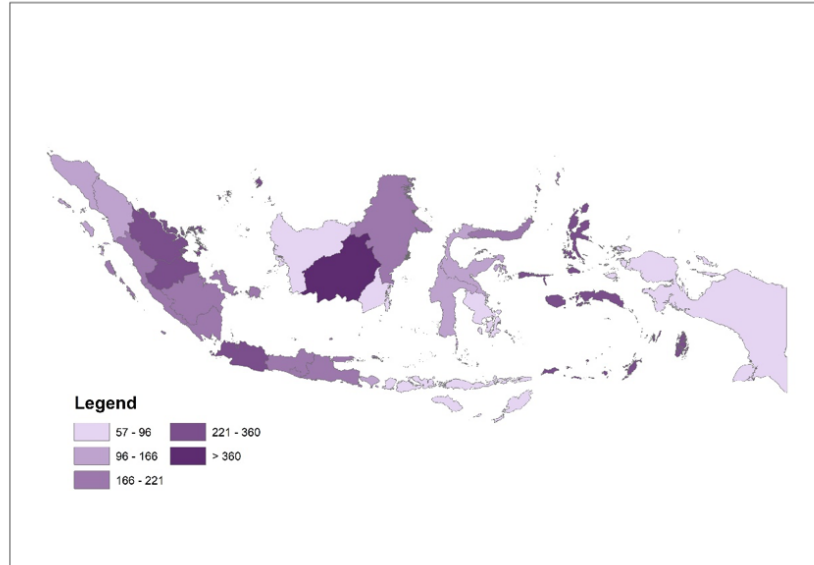
A similar level of geographic heterogeneity applies also to fuel prices. As fuels need to be transported mainly by trucks, but also by sea vessels, the price of fuel is extremely sensitive to disruptions to the transportation network, roads in particular. Events such as the closure of a road, disruption in naval shipment or technical failure of a supplier’s transportation equipment add substantial randomness to the propagation of nationally mandated prices energy prices.¹⁴ The provinces with lower transport infrastructure density are expected to suffer more significantly from such negative shocks given the paucity of viable alternative routes. Panel (b) of Figure A2 provides suggestive confirmation of this hypothesis by showing a negative correlation between changes in fuel prices and the period-average kilometers of highway per square kilometer of the province area.

The empirical analysis will rely on such geographic variation of electricity and fuel prices over time to extract the exogenous local component of price changes over time.

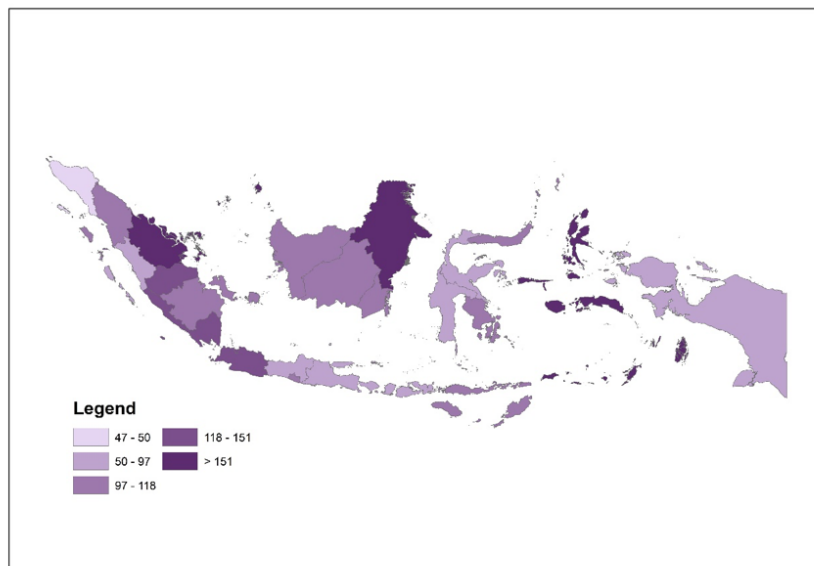
¹⁴In some cases, variation is induced by policy. For instance, frequent shortages have prompted authorities to approve higher tariffs in remote areas to unlock local small-scale supply from independent utilities (IEA, 2014). In an attempt to address these large price differences, in 2016 the Government of Indonesia has started the implementation of a “One-price Fuel Policy” program, which however falls beyond the period of our analysis.

Figure 2: Province-level change in electricity and fuel prices: Indonesia

(a) Growth in electricity prices (%)



(b) Growth in fuel prices (%)



Note: Electricity prices include PNL and non-PNL electricity purchased from the grid. Fuel prices refer to gasoline, diesel and lubricants. Individual energy types are aggregated in the two categories by using their consumption shares for each plant. Energy prices are expressed in real terms using two digits-industry price deflators.
Source: Authors' calculations with data from SI.

2.2 Mexican energy markets

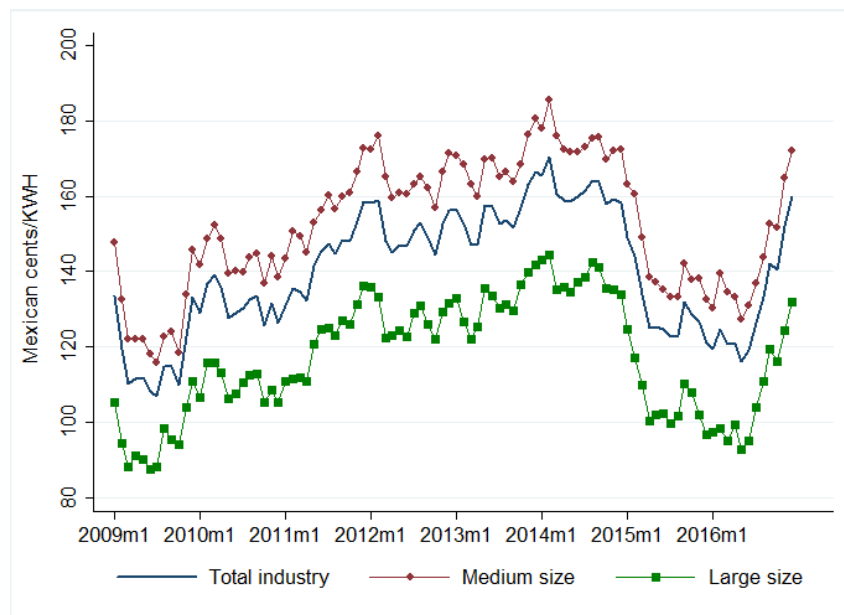
In Mexico, the Secretaría de Hacienda y Crédito Público (Ministry of Finance, abbreviated as SHCP) is the lead institution in setting prices for both electricity and fuels. SHCP sets electricity prices including the subsidization for agricultural and residential sectors. Mexico has a complex electricity tariff scheme with 32 electricity tariffs varying by region (16 regions), type of user (residential, commercial, agricultural, industrial, and public services), and seasons. If we focus on medium and large companies, there are 14 tariffs. In this sense, the tariff that a firm faces will be determined by infrastructure availability and the level of consumption.¹⁵ In the first panel of Figure 3 we summarize the evolution of industrial prices by size of the industry. As the figure shows, on average, medium-size firms face a higher price. The mean prices for the four main tariffs applied to medium and large firms (second panel of Figure 3) also display substantial variation. Tariffs are different depending on how the firms connect. Firms that directly connect to high-tension transmission lines (HT) pay lower average prices than firms connecting to lower tension transmitter. It is also worth noting the significant drop in price in 2015. That is due to a reduction in electricity tariffs determined by SHCP and the Comisión Federal de Electricidad (Federal Electricity Commission, CFE), which aimed at generating incentives for transitions towards cleaner sources of energy.

Historically, fuel prices and controls were subject to the determinations established by the federal government through the SHCP. These prices have been gradually adjusted over time, mostly through monthly increases. From 2006 to 2014, gasoline and diesel prices in Mexico were below market prices through a control mechanism in the form of the Impuesto Especial sobre Producción y Servicios (Special Tax on Production and Services, IEPS). This tax could be positive (when market references were below local prices) or negative (when market references were above local prices). During this period, the negative tax worked as a subsidy, reimbursing this price gap to the national oil company. Also, prices at the border with the United States of America followed a similar regime, although try-

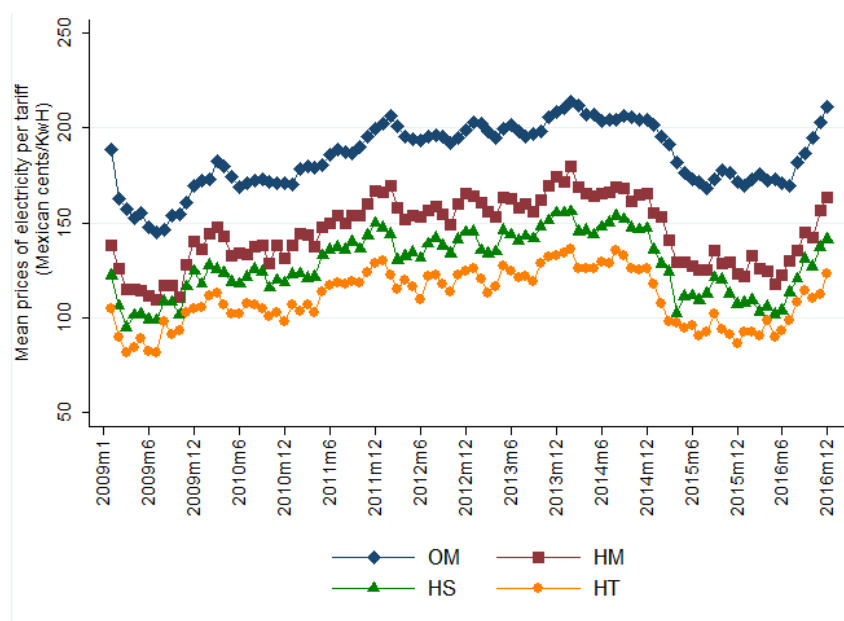
¹⁵For industrial and commercial users, tariffs are mainly set by tension lines used, hourly prices and the marginal costs of the Comisión Federal de Electricidad (Federal Electricity Commission, CFE) for providing the services.

Figure 3: Evolution of electricity prices: Mexico

(a) Mean prices of electricity by size of industry, 2009-2016 (Cents/KWh)



(b) Mean prices of electricity by main industrial tariff, 2009-2016 (Cents/KWh)



Note: OM: Ordinary medium voltage; HM: Hourly medium voltage; HS: Hourly high voltage sub-transmission; HT: Hourly high voltage transmission.

Source: Secretaría de Energía (Ministry of Energy, SENER).

ing to standardize them with those in the United States to maintain local industry and *maquila* competitiveness. Eventually the approval of the Energy Reform in 2014 set out a gradual phase-down of the fuel subsidies. This was accompanied by the tax on fossil fuels in the same year discussed above. While this was not as ambitious as initially envisaged, it supported an inversion of trend away from subsidization of fossil fuels.¹⁶

Since the creation of the Comisión Reguladora de Energía (Energy Regulatory Commission, CRE) in 1993, the natural gas prices have been set according to international references located in the Gulf of Mexico, and adjusted through a net-back mechanism to balance the availability and opportunity cost between domestic production in the southeastern region in Mexico and the imported gas from the United States. Later, with the development in Mexico of liquefied natural gas (LNG) facilities to import this fuel from other regions, price references from the Gulf Coast and the West Coast of the United States have also been used.¹⁷

In addition, price definitions fall now under the jurisdiction of the CRE in coordination with the Comisión Federal de Competencia Económica (Federal Economic Competition Commission, COFECE). They are mandated to determine prices and price methodologies according to market conditions, opportunity costs of foreign fuels trade and international competitiveness conditions. The government sets maximum prices for fuels, but they tend to disappear as market conditions settle, required logistics infrastructure is developed and more participants join in. Also, the government could determine focalized incentives in order to maintain competitive prices in rural and marginal urban areas.

In Figure 4, we present the evolution of average fuel prices between 2009 and 2015. As depicted in the figure, a drop in the average price occurred in 2010, following the trend observed in the international markets. Additionally, in 2015, there was a reduction in the average prices which was mainly driven by the prices of natural gas, which hold an average share of 56% of fuels consumption in the

¹⁶During 2015, low fuel price references led to a positive IEPS tax that was followed by the revision of the price formula in 2016, in preparation for the final liberalization of prices in 2018. This revision introduced minimum and maximum price caps that were updated in a periodical basis. In case of a market price above the maximum price cap, the formula contemplated a IEPS tax break to meet this cap.

¹⁷Currently, the price structure for this fuel is regulated by the CRE and takes into consideration the costs of transportation, distribution, additional services and other factors.

manufacturing sector.

Figure 4: Evolution of Average Fuel prices 2009-2015



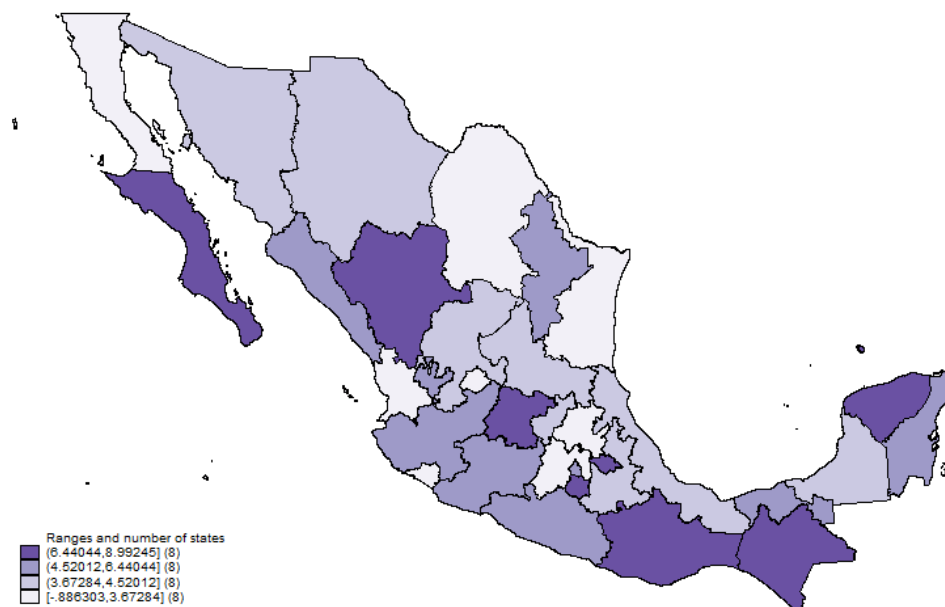
Note: Fuel prices are calculated as a weighted average of the prices of coal, petroleum coke, diesel and natural gas using 3-digits NAICS consumption as weights
Source: Authors' calculations with data from SENER.

At the regional level, as shown in Figure 5, we observe that in real terms, electricity prices, weighted by the corresponding industrial tariff, increased more in states of the south-east, which further decreased the competitiveness of states that were already deprived in terms of development. Other states that exhibit the highest increases in electricity prices are the ones in the center of the country (the state of Mexico and Mexico City). Regarding fuel prices, on average, reductions in fuel prices are observed, mainly driven by the drop in natural gas prices, but it is important to note that once again the south is where increases or lower reductions in state-average prices are observed. The same is observed in states near the capital city.

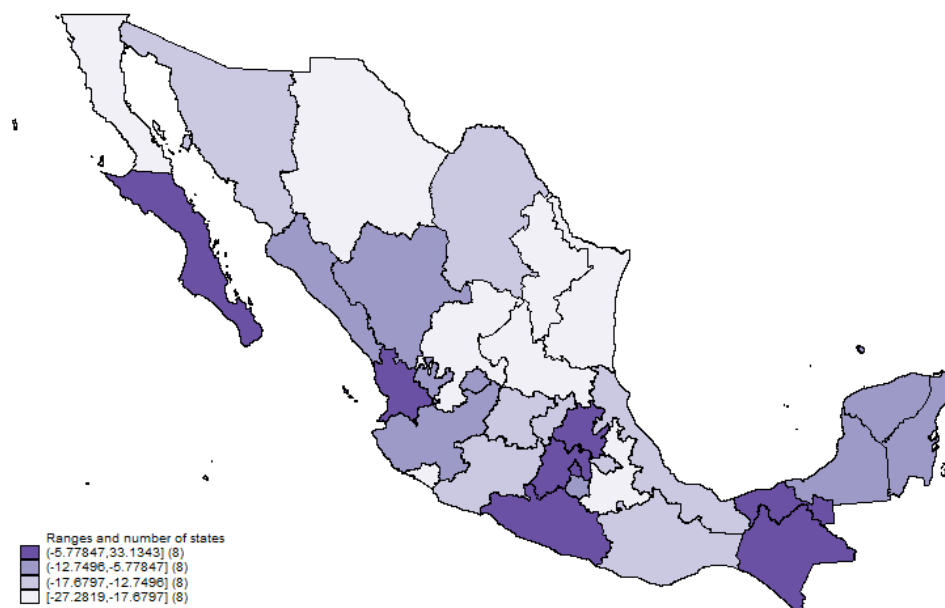
In the section below, we match these national, regional and sectoral mandated prices with plant-level information to construct plant-specific energy prices for Mexico.

Figure 5: State-level change in electricity and fuel prices: Mexico

(a) Growth in electricity prices (%)



(b) Growth in fuel prices (%)



Note: Electricity prices are weighted by the tariff that correspond to each user using data from the EAIM. Fuel prices are calculated as a weighted average of the prices of coal, petroleum coke, diesel and natural gas using 3-digits NAICS consumption as weights.
Source: Authors' calculations with data from SENER.

3 Data

Both Indonesia and Mexico maintain some of the most detailed manufacturing plant-level datasets available in developing countries. These include information on expenditure of energy consumed by energy source, investment by type of asset and other key information on production that can be used to estimate productivity. The plants are tracked over time with very high response rates, which makes the panel representative in every year. That is unusual especially for developing economies, for which the scarcity of granular data has constrained the evidence on the impact of environmental policies on firms' performance.

3.1 Indonesian Data

Plant level data are taken from the Indonesian survey of manufacturing plants with at least 20 employees (Statistik Industri) administered by the Indonesian statistical office (BPS). The coverage of the survey is extensive; in fact it becomes an actual census in 1996 and 2006 and it is very close to a census in the remaining years, hence ensuring high representativeness even at the provincial level. Plants are grouped into 5 digits sectors following the definition Klasifikasi Baku Lapangan Usaha Indonesia (KBLI), a classification mostly compatible with ISIC Rev.3. The KBLI classification has been adjusted to be consistent over the whole sample, ranging from 1998 to 2015. The data also include information on products defined at a more refined level (9-digit Klasifikasi Komoditi Indonesia), which we use in the computation of product level TFPQ as explained below. The plant level data provide information on several variables such as output, capital stock, employment, materials and energy usage (price and quantities) by type of energy.¹⁸

In particular, electricity consumption refers to electricity purchased from PLN, which accounts for the majority of electricity expenditures and that purchased from other providers. Fuel consumption includes diesel, gasoline and lubricants, which together to electricity account for over 80% of all energy consumption.¹⁹ Since

¹⁸To maximize the reliability of the data, we dropped an observation from the raw sample when at least one of the variables used in the analysis had an implausible value. For instance, we dropped an observation when a plant reported expenditure on fuel and electricity larger than its revenue.

¹⁹The Indonesian survey asks manufacturers about expenditures and quantities of PLN and

the focus of this paper is on the distinction between fossil fuels and electricity, we categorize each energy type used by the plants into one of the two groups. To do so, we convert consumption of fuel in kWh equivalents and compute plant-level quantity shares in order to capture the relative importance of each source.²⁰ The shares sum to one within each category. To avoid potential endogeneity of time-varying proportions, for each plant we fix shares in the first year of observation and then drop that year from the sample.²¹

One of the key challenges of the Statistik Industri data is the lack of complete series of capital stock. Earlier studies tried to re-construct capital stock series applying the perpetual inventory method (PIM) to the first year of capital stock data reported by the plant (Amiti and Konings, 2007; Javorcik and Poelhekke, 2017). However this imputation method crucially relies on the capital value self-reported by the plant the first year the data are available, which is not necessarily accurate.²² One potential advantage of using PIM is that purchase and sales data might be more accurate relative to the self-reported value of the stock, requiring an appropriate calculation of market values and depreciation. However, PIM needs to rely on measures of capital depreciation, which are difficult to accurately estimate. To mitigate such trade-off, we have adopted a hybrid strategy. We first clean the self-reported data, adopting an algorithm which keeps only observations that fulfill a battery of tests.²³ Then, we apply the PIM only to fill the gaps between the missing observations and reapply the battery of tests to ensure consistency of the series.

Finally, output price deflators are constructed by matching wholesale BPS price indexes available at the 5 digits level IHPB classification (Indeks Harga Perdagangan Besar) with KBLI. Moreover, we are able to obtain different capital deflators

non PLN electricity, gasoline, diesel, kerosene, coal, gas, LPG, lubricant, oil diesel, oil burn, charcoal, firewood, coke plus a category labelled “other fuels”. However, exception made for PLN, non-PLN electricity, diesel, gasoline and lubricants, all other sources have been included in “other fuels” in some years. Therefore, to minimize noise, we limit the analysis to the energy sources that have been separately identified in every year in the sample.

²⁰We used the following standard conversion factors: 1 litre of Diesel corresponds to 10 kWh; gasoline: 9.1 kWh; lubricants: 11 kWh.

²¹A similar strategy can be found in Marin and Vona (2017).

²²In particular, there is no a priori reason to believe that the quality of the self-reported capital stock the first year is necessarily better than the value in other years.

²³The procedure is described in the appendix.

depending on the type of asset. We distinguish general price deflators from machinery and equipment, vehicles, and buildings. For all deflators, 2010 is used as the base year.

3.2 Mexican Data

The main source of plant-level data is the Encuesta Anual de la Industria Manufacturera (Annual Manufacturing Industry Survey, EAIM), conducted by the Instituto Nacional de Estadística y Geografía (National Institute of Statistics and Geography, INEGI). The survey provides yearly statistically representative information on production, employment, investment by asset type at both national and NAICS-6-digits level for the period 2009-2015. We match this data with the Encuesta Mensual de la Industria Manufacturera (Monthly Manufacturing Industry Survey, EMIM), which includes the same sample of manufacturing plants as the annual survey in order to obtain the monthly production of each plant at the beginning of the period, which is useful to construct energy price series as explained below. All variables included in the analysis are winsorized at the 1% and 99% levels.

Unlike in the Indonesian data, an important limitation of the EAIM survey is the data on energy consumption does not include any information on quantities and the data only distinguishes between electricity consumption and other fuels. This makes it more challenging to to construct plant-level energy prices by source. In order to address this limitation, we collected detailed data on official electricity and fuel prices from different sources. Further detail on this procedure is provided in the following sections.

3.2.1 Electricity prices

As previously mentioned, for Mexico, we don't have electricity firm-level prices as the manufacturing survey only requests information about consumption in value (in MXN pesos) of electricity and not in quantity terms. Therefore, we had to combine firm-level information (about monthly consumption value of electricity) with external information from the Federal Commission of Electricity (CFE) and the Ministry of Energy (SENER). Relying on these Administrative data of elec-

tricity bills and users, we were able to estimate the price or tariff paid by a user as a function of the firm's consumption value.²⁴ Finally, for each plant we translate these monthly tariffs into annual tariffs by computing the average monthly tariff weighted by the plant-specific monthly production shares in 2009 (from the EMIM). For plants that enter the survey after 2009, we use the first year in which the plant appears to compute weights.²⁵

$$P_{it}^e = \sum_{m=1}^{m=12} \frac{y_{im0}}{\sum_{m=1}^{m=12} y_{im0}} P_{imt}^e \quad (1)$$

where P_{it}^e is the average electricity price that plant i faces in year t ; y_{im0} is the revenue of i in month m in year 0 and P_{imt}^e is the price that i faces in month m and year t .²⁶

3.2.2 Fuels prices

To construct plant-level fuel prices, we follow four steps. First, using consumption data from SENER, we identify the four main types of fossil fuel used in manufacturing. These are natural gas, diesel, petroleum coke, and coal and account for 85% of other fuels consumption, and 68% of total energy consumption in manufacturing. Second, we derive the shares of the four fuels in total fuel consumption of each NAICS 4-digits manufacturing sector in 2009.²⁷ Third, we compute monthly sector-specific fuel price indices by combining this data with monthly national prices for diesel (from SENER), for coal and coke (from INEGI) and with monthly-regional prices for gas (from SENER). More formally we compute the following:

²⁴Users pay a specific tariff out of the four main different tariffs that a firm could pay (two for medium-sized companies and two for large companies), depending on consumption brackets.

²⁵To test the robustness of these weights, we used alternatively current year weights and the results - available from the authors upon request - do not change significantly.

²⁶Thus, we assume that energy consumption is proportional to production volumes over the year. For each plant we compute shares in 2009 to avoid potential endogeneity of time-varying proportions.

²⁷To do that we convert fuel consumption in kWh equivalents by using the following conversion factors: 1 liter of diesel corresponds to 10 kWh; 1 kg of coal is equivalent to 8.1 kWh; 1 m^3 of natural gas is equal to 11.7 kWh, and 1 kg of coke is equal to 8.8 kWh.

$$P_{sRm}^f = \alpha_s^{coal} P_m^{coal} + \alpha_s^{coke} P_m^{coke} + \alpha_s^{diesel} P_m^{diesel} + \alpha_s^{gas} P_{Rm}^{gas} \quad (2)$$

where α_s^d are the shares of fuel type d in total consumption of fuels in sector s and P_m^d are the national prices of fuel d in month m for coal, coke, and diesel and monthly regional (R) prices for natural gas. The final step consists of weighting these monthly indices with plant-level monthly production from EMIM using the same approach as equation 1. This generates estimates of the yearly price of fuels faced by each plant.

3.3 Performance Measures

We are interested in the impact of energy prices on alternative measures of firm performance. Our main productivity indicator is an index of revenue-total factor productivity, as in Aw et al. (2001).²⁸ For each plant f from sector τ and year t ,

$$\ln(TFPR)_{f\tau t} = [\ln(Y_{f\tau t}) - \ln(\bar{Y}_{\tau t})] - \left[\frac{1}{2} \sum_{j=1}^k (S_{jf\tau t} + \bar{S}_{j\tau t})(\ln(X_{jf\tau t}) - \ln \bar{X}_{j\tau t}) \right]$$

In the above equation, $Y_{f\tau t}$ is the gross product of the plant, S_{fjt} is the cost share for input j and X_{jft} real value of the same input.²⁹ As it is standard in the literature, we consider capital, labor, and other materials as factors of production see (See Foster et al., 2008). Upper bars represent averages within a sector and year.

Using a productivity index has several advantages in our framework. First, the index expresses each plant's input and output as deviations from a reference point, in our case the country-industry's average plant.³⁰

²⁸This methodology has been widely employed in previous studies, e.g., Topalova and Khandelwal (2011); Pavcnik (2002); Delgado et al. (2002).

²⁹To calculate the cost shares, following Foster et al. (2008), we first had to estimate the rental rates of capital, which we multiplied to the real rental stock we had. In the case of Mexico, we use annual information from the KLEMS estimates(INEGI) to calculate these rates at the NAICS three digits level. For Indonesia, we approximate the user cost of capital with the sector-year average value of the ratio between the book value and the real stock of capital.

³⁰As Delgado et al. (2002) mention, the use of a reference firm that varies across industries has the advantage of removing the productivity differences across sectors when pooling together

Therefore, the index is insensitive to the units of measurement and especially well-suited for an analysis based on two different countries. The second advantage is its non-parametric nature. In particular, given the focus of this paper on technology, it seems restrictive to impose the shape of the production function. Parametric approaches such as those developed in Olley and Pakes (1996), or Akerberg et al. (2015) would allow some heterogeneity across sectors, but they would still assume a fixed technology over time. Third, TFPR is also a measure of profitability as it indicates how many dollars of revenue the firm gets for each dollar of inputs expenditure. This is particularly appealing for our purposes since the Porter Hypothesis implies that plants are making a "mistake" by not switching to electric machinery. Fourth, TFPR has the advantage of being directly related to TFPQ (see below), and also allows to take into account investments in capital assets, which is a key mechanisms at play here. As a result, TPFR allows us to capture the part of the impact of energy prices on profitability via the pure technical efficiency channel and assets accumulation.

An important concern is that the TFPR index might be a biased indicator of technical efficiency, because it is based on revenue and so it might capture changes in prices and markups. For this reason, we also estimate TFPQ De Loecker et al. (2016). We leverage information on quantities and values of nine-digit products produced by each plant. This allows us to address two important sources of bias. First, using quantities rather than values in our estimation routine, helps us overcoming the bias resulting from deflating plant-level variables with industry-level deflators. That would imply assuming that all plants within an industry charge the same output prices and faces the same input prices. This would clearly be a strong assumption, since plants differ in variety and quality of their products and inputs. Specifically, to control for input price bias, we build an input price control function including output prices (which we observe at the product-level), market shares to account for the potential impact of market power, industry and location dummies.³¹

Second, by observing quantities and values of multi-product plants, we can

data from different industries.

³¹Following De Loecker et al. (2016), we use a polynomial in all such variables to implement the price control function.

address input allocation-bias. Input allocation bias might arise because in the data we do not observe how inputs (e.g. capital, labor and materials) are allocated to the production of each product. The essential features of our methodology is using a sub-sample of single-product plants to estimate the parameters of a flexible trans-log production function. Then, in a second step we back out allocation of inputs across products within a multi-product plant using an optimisation algorithm.

Failing to account for these sources of bias can result in biased estimates of marginal costs and thus, estimated total factor productivity. An extensive discussion on input price and input allocation bias can be found in De Loecker et al. (2016), which also provide details on the estimation methodology.³²

We complement the analysis testing for the impact of energy prices on alternative measures of plants' performance, including (log of) real value added per worker and value added minus payments to labor and capital, which is a measure of operating profits. As the latter can also have negative values, we use the inverse hyperbolic sine transformation to account for them.³³ Finally, we also test the impact of energy prices on a measure of energy efficiency, defined as the log of real value added per KWh-equivalent of total energy consumed.

Table A1 of the appendix reports the summary statistics in both countries for the main variables used in the analysis.

4 Identification Strategy

Our objective is to measure the impact of changes in electricity and fuel prices separately on plant-level outcomes. Simply regressing outcomes on prices might result in biased estimates due to the potential endogeneity of energy prices. For instance, product or plant specific demand shocks could generate an increase in economic activity affecting both energy prices and plant-level investment, sales and/or

³²Ideally, to allow for different output elasticities, we would include the quantity of electricity and fuel (in KWh-equivalents) as distinct production factors. However, this would be too demanding on the data, because it would increase exponentially the number of terms to be estimated.

³³In the case of Mexico, plants with negative or zero profits represent only 11% of the whole sample, and the number is quite similar across the different years covered. Furthermore, they do not exhibit a different regional pattern than the whole sample. ADD SIMILAR SENTENCE FOR INDONESIA.

prices. Reverse causality could also be an issue, as technology shocks or local infrastructure development might drive down the cost of energy and boost plants' performance. To mitigate these issues, we include two-digits sector-year dummies accounting for changes in market conditions and development in sector-specific technologies. We also include region-year fixed effects to control for differences in long-term changes in local development and infrastructure availability.³⁴

However time-varying unobserved variables at the plant level would not be controlled for by the inclusion of plants' fixed effects. That would be the case for example if hiring a new high-ability manager boosted a plant's performance and affected energy prices faced by the plant, for example by negotiating lower energy prices with local suppliers, or by maximizing energy consumption during non peak hours. Similarly hiring a politically connected manager could result in larger profits and preferential energy rates.

In order to address these concerns we instrument plant-level energy prices with plausibly exogenous sources of variation as explained below. With valid instruments for plant level energy prices, we estimate the following system of equations separately on the Indonesian and Mexican samples:

$$P_{ft}^i = \alpha_0 + \alpha_1 inst_{ft}^i + D_{st} + region_{rt} + u_f + \eta_{ft} \quad (3)$$

$$Y_{ft} = \beta_0 + \beta_1 \hat{P}_{ft}^{fuel} + \beta_2 \hat{P}_{ft}^{elec} + D_{st} + region_{rt} + u_f + \varepsilon_{ft} \quad (4)$$

In (3), $inst_{pt}^i$ is the respective instrument for energy prices. The second stage (4) relates energy prices to plant-level outcome, Y_{ft} . Sector-year dummies (defined at 2-digit ISIC level) are denoted by D_{st} , while $region_{rt}$ are island-year (Indonesia) or state-year (Mexico) fixed effects. The term u_f is the plant fixed effect. In (3), $i = \{fuel, elec\}$. The empirical specification includes separately fossil fuel and electricity prices. That allows us to disentangle the effects of the two sources of power. Moreover, since fuel is used to generate electricity, including both prices

³⁴Regions correspond to the 6 main islands of the archipelago for Indonesia (Sumatra, Java, Bali & Nusa Tenggara, Kalimantan, Sulawesi, and Maluku & Papua), and 32 states for Mexico.

mitigates the concern that the instrument for fuel prices could affect plants' performance through its impact on electricity prices, which would invalidate the exclusion restrictions. At the same time, grouping together electricity types and fossil fuels eases the interpretation of results and mitigates potential correlation across prices for different energy sources, which might inflate the standard errors of the individual coefficients.

In equations (3) and (4), hats indicate that plant-level energy prices are estimated. For Indonesia, average unit prices are obtained by dividing plant-level energy expenditure by energy consumption. For Mexico, \hat{P}_{ft}^i is an index obtained by weighting sector-month-specific prices (sector-month-region-specific prices for natural gas and electricity) by plant-specific monthly production in a given year.³⁵

After controlling for economy-wide and sector-specific market factors, as well as for plants' unobserved characteristics, identification of our coefficients of interest is obtained estimating the system (3) - (4) and comparing plants' outcomes over time in plants facing different changes in energy prices.

4.1 Instrumental Variables

Given the differences in the construction of the energy prices series and in the institutional contexts of Indonesia and Mexico, we follow two different strategies to construct IV for prices. For Indonesia, we exploit our data to isolate the geographical markup on energy prices due to shocks to the cost of distributing energy to a particular province. We proceed as follows. First, we compute for each plant f and energy type i , the average price paid by other plants in the same province p in a given year,

$$\hat{P}_{fpt}^i = \sum_{f' \in p, f' \neq f}^{N_{pt}} \frac{\hat{P}_{f't}^i}{(N_{pt} - 1)} \quad (5)$$

where $N_{p,t}$ is the number of plants in a province and year.³⁶ A valid instru-

³⁵Such differences suggest that endogeneity should be more of a concern for Indonesia, while mis-measurement might affect more severely Mexico.

³⁶In the absence of information on energy price determinants, in (5) we assign equal weight to the average plant price $\hat{P}_{f't}^i$. This assumption allows us to focus on the geographical determinants of energy prices, which is the key source of variation exploited by the instrument.

ment must affect plants' performance only through its impact on plant-level prices. Thus, excluding the plant in question from the computation of the average provincial price mitigates the possibility of the instrument violating the exclusion restrictions. Then, we compute the geographical energy markup,

$$\mu_{fpt}^i = \frac{P_{fpt}^i}{\bar{P}_t^i}$$

where \bar{P}_t^i is the country-average price of energy source i . From the discussion on energy prices above, the markup μ_{fpt}^i should capture the (time varying) cost of distributing energy to users in a particular province, which should not be correlated to plant-specific factors. The inclusion of a full set of sector-time and region-time controls in (4) relieves the concern that these instruments may be picking up sector demand or local-level dynamics such as fluctuations in demand, production or infrastructure development, which can drive both prices and performance, thus not fulfilling the exclusion restrictions. To further account for time varying confounders at the provincial level factors, we also control for province-level real GDP.

Energy prices for Mexico are less exposed to endogeneity concerns, as they are computed on the basis of administrative information that should not be subject to the plant-specific endogeneity described above. The inclusion of state-year and sector-year effects in our empirical specification further mitigates the concern that mandated prices might respond to sectoral, regional or size characteristics that are partially correlated with plant outcomes. However, the price indices also are a function of plant-specific monthly output, and therefore, potentially endogenous. For this reason, we also instrument plant-level price indexes for Mexican plants through a similar leave-out type approach as for Indonesia. Specifically, we take the average price at sector-state level, excluding the plant analyzed.³⁷

One potential concern with our identification strategy is that common industry or regional shocks might affect both endogenous prices and the instruments. For instance a boom to a specific manufacturing sector (for instance because of increased access to export markets) may raise energy prices because of capacity

³⁷We also tested alternative instruments analyzing the average index within state but excluding own sector, and average index within sector but excluding own state. The results, available upon request, are robust to these different specifications. 90% of the groups used for this analysis have more than 18 observations and, furthermore, 50% have more than 42.

constraints. This shock will bias both the energy price coefficients even when using the instrument. However, the inclusion of a full set of industry-year and region-year fixed effects in equation (4) is likely to address the endogeneity concerns arising from such shocks. In particular, industry-year effects should control for shocks that may affect all plants in a sector, defined at 2-digit ISIC level, which represents a relatively high level of disaggregation. In addition region-year fixed effects should address potential geographic shocks such as infrastructure construction and localized weather shocks.³⁸

The instruments precisely predict plant-level energy prices in both countries, as shown in the first stage regressions in Table 1. In Indonesia, the IV for fuel has a small positive impact on plant-level electricity prices. This might be explained by the fact that electricity requires fuel for its generation, and so the higher costs pass on to electricity prices. It should be noticed that this does not violate the exclusion restrictions, as we estimate the impact of electricity and fuel prices simultaneously.

5 Results

Table 2 presents 2SLS estimates of the impact of energy prices on plants' performance. The coefficient on fuel prices is always positive and significant for both countries. A 10 percent increase in fuel prices increases TFP_R by 1.4 percent in Mexico and 1.6 percent in Indonesia. A positive effect is also found for labor productivity (respectively 2.4 percent and 1.8 percent for Mexico and Indonesia) and for net profits. A 10 percent increase in fuel prices increases profits by 14 percent in Mexico and 18 percent in Indonesia. Plants also become more energy efficient as a result of fuel price hikes, with increases by 2.2 percent in Mexico and 7 percent in Indonesia as a result of a 10 percent price increase.

This positive effect does not apply to electricity prices, for which the results are in line with the existing evidence of a negative impact of electricity prices on firms' performance (Abeberese, 2017; Marin and Vona, 2017).³⁹ For Mexico, we

³⁸For Indonesia, the concern is further alleviated by the inclusion of province-level GDP as a control.

³⁹Related evidence consistent with the positive impact of electricity on firms' performance is found in Kassem (2019) for Indonesia, Fried and Lagakos (2019) for Ethiopia, and Allcott et al. (2016) for India.

find that a ten percent increase in electricity prices lowers TFPR (-4.1 percent), labor productivity (-2.4 percent), and profits (-29 percent); unlike for the other performance measures, an increase of electricity prices increases energy efficiency. In the Indonesian sample, a ten percent increase in electricity prices lowers TFPR by 0.3 percent. The coefficient on labor productivity is close to zero and not significant, while the coefficient on profits is negative and significant. For energy efficiency the impact of electricity prices is positive, as in the case of Mexico.

In the case of Mexico the energy prices are defined at the sector-state-year level. As we can only observe state-level variation in prices for gas, we test the robustness of the results to computing standard errors through a bootstrapping procedure that re-samples the underlying time-series (we implement 1,000 replications to generate the errors' distribution). The coefficients of energy prices resulting from these procedures remain highly significant (results available from the authors upon request).

A comparison with the OLS counterparts of these estimates (see Table A2 in the appendix) reveals two interesting patterns. First, the endogeneity appears to exert a downward bias to the estimated fuel coefficient, which tends to be positive but smaller than the IV coefficient. This could be the case for instance if an unobserved positive productivity shock to the plant (e.g. the hiring of a good manager) improves performance and reduces the fuel price paid by the company (e.g. the manager is able to source fuel more cheaply). Second, for Indonesia, the endogeneity bias for electricity prices goes in the opposite direction. This would be consistent, for example, with a positive shock (e.g. an increase in demand) leading to an increase in the plant's installed electricity capacity, which moves the plant to a higher electricity tariff.

One important difference between the two samples is the longer time period covered in the Indonesia dataset (1998-2015) as opposed to Mexico (2009-2015). Table A3 of the appendix shows that the results hold - and are in fact even larger in magnitude - when we restrict the Indonesia data on the period 2009-2015.⁴⁰ The larger impact of fuel prices on performance in the latter period is consistent with

⁴⁰This restricted sample also addresses the possible concern that the longer time period includes the post-East Asian crisis and Indonesia's democratic transition, which may affect the estimated effects

the idea that as the pace of development of new electric technologies increases over time, so does the opportunity cost of employing old and inefficient fuel-powered machinery increases.⁴¹

To the best of our knowledge, such an asymmetry in the impact of prices across different sources of energy has not been documented before. In particular, the result that an increase in fuel prices can boost performance is remarkably similar across the two countries in spite of the differences in the data, the instrumental variables and the structure of the two economies.

This asymmetry is consistent with the fact that fuels and electricity tend to power different types of capital equipment. Old technology is embodied in capital vintages that are more likely to be powered by fuel, while new technology tends to be embodied in electric capital vintages.

A technology that is especially relevant in our framework is the heating system, which is used extensively in manufacturing to shape components or transform materials. This system typically accounts for a relatively large share of the energy consumed by manufacturing firms. Old generations of boilers are powered by coal or gasoline, while electric boilers are more common among the new generations (Malek, 2005). Electric-powered boilers are more efficient at generating heat than fuel-powered ones, because the latter uses the atmosphere to deliver oxygen to the combustion process and the atmosphere only contains 20.7 percent oxygen. The other 79.3 percent is essentially nitrogen, which must be heated in the burner, resulting in losses of energy discharged into the atmosphere. Similarly, the arc furnace, an electric heating system, came to replace the older blast furnace powered by fuel. Thus, an increase in fuel prices may induce plants to scrap old fuel-powered machinery and purchase new electric or hybrid (fuel- and electric-based) equipment. Case studies evidence suggest that electric heating technologies are not only more energy-efficient, but also able to generate non-energy productivity gains, such as better product quality, process flexibility, speed and reliability (EPRI, 2007).

⁴¹An alternative explanation might relate to the recovery from the global financial crisis in 2008-09. However, Indonesia was only marginally affected by the crisis given its limited integration with the global economy. In addition the interaction of the (linear) time trend with the fuel price is positive in both countries (results available from the authors upon request), casting further doubts that this may have to do with the global recession.

Since electric machinery is more productive and energy-efficient, the negative effect of the fuel price increases is compensated by the positive effect on technological upgrading, with a potentially positive net effect on performance. It follows that electricity price hikes do not trigger substitution, because electric technologies are less likely to be outdated; hence, the negative impact on performance.

5.1 Energy Prices and Technology Upgrading

We turn to testing this mechanism. Our working hypothesis is that fuel price hikes trigger technology upgrading towards electric machinery, and that electricity-powered machinery is more productive than fuel-powered machinery. In line with this hypothesis, we should observe that upon an increase in fuel prices, plants invest in electric machinery and increase their technical efficiency.

Although our data provide information on sales and purchases of capital by type of asset, we cannot observe whether transactions on equipment refer to machinery powered by fuel or electricity. However, using energy consumption data we can infer changes in capital composition by looking at the energy content of plants' capital stock. Columns 1 and 2 of Table 3 show that an increase in fuel prices boosts machinery turnover, as measured by the absolute value of the sum of purchase and sale of machinery.⁴² At the same time, electricity prices tend to have a negative impact on turnover, which could plausibly capture a negative income effect.⁴³

Table A4 in the appendix displays the result of a placebo experiment, showing that as expected, fuel prices do not have an impact on turnover of buildings and land. The price of fuel does affect turnover of vehicles, which heavily on combustible fossil fuel. These results reassure us that the effects of energy prices on machinery turnover shown in Table 3 are not an artifact of the data.⁴⁴

⁴²Given the lumpiness of investment data at the plant level, we smooth the series by constructing a measure of machinery turnover (sales + purchase of machinery and equipment), which allows us to use OLS. The logs of the residual zeros are replaced with zero. We also experiment using the transformation $\ln(1 + x)$, which delivers similar results.

⁴³For the case of Indonesia, a higher number of available observations allows us to assess the impact of energy prices on purchase and sales of equipment separately. We find that fuel prices increase both purchase and sales of equipment. On the contrary, electricity prices reduce turnover by lowering purchase only. That is consistent with our hypothesis of technology upgrading. These results are available upon request.

⁴⁴Electricity prices tend to have a negative impact on turnover of other categories of assets in

In order to shed light on the type of machinery that plants switch to, columns 3 and 4 of Table 3 examine the impact on the electricity content of capital in both countries. We argue that this measure may capture better this switch than the more traditional measure of electricity in total energy consumed by the plants, which might also be affected by the investment made by plants. This could lead the share of electricity to change for reasons other than fuel-electricity substitution. Consistently with the hypothesis that fuel price hikes induce substitution towards electric machinery, we find that an increase in fuel prices raises the electricity content of capital.

If our hypothesis is correct and fuel prices induce plants to switch to electric technologies, we should observe a long-lasting increase in electricity usage over fuel. Figure A1 in the appendix shows the estimated coefficients of two year leads and six years lags of fuel prices on KWh of electricity consumed over KWh equivalents of fossil fuels. We conduct the experiment with the Indonesian sample, as the length of the Mexican sample appears to be insufficient to include all the relevant leads and lags.⁴⁵ The lead values of fuel prices are not statistically significant, which reassures us against the potential presence of pre-trends. The figure suggests that the bulk of the effect of fuel prices takes place on impact, which justifies our econometric specification including only contemporaneous values. Consistent with our hypothesis, fuel price hikes have a positive and long-lasting increase in the consumption of electricity over fuels.

Columns 5 and 6 of Table 3 show that an increase in electricity prices lowers the fuel intensity of capital in Mexico, while the coefficient is not significant for Indonesia. The own price elasticities are negative as expected. The last columns of Table 3 show that, consistently with our hypothesis of technological upgrading, an increase in fuel prices also increase plants' technical efficiency as measured by quantity-total factor productivity (TFPQ).

We add further evidence on this mechanism by exploiting another source of

Mexico, which is consistent with a negative income effect.

⁴⁵Instrumenting all leads and lags results in a very weak first stage given the large number of endogenous regressors and instruments. Therefore, we only instrument the contemporaneous values of electricity and fuel prices, while assuming that the respective leads and lags are exogenous to current energy consumption. Because of that the results in Figure A1 should be interpreted with a note of caution.

heterogeneity in electrical grid quality across provinces and years. Did places with low-quality grids not adopt electrical machinery? The results for Indonesia are shown in columns 1 and 2 of appendix Table A5.

We interact fuel prices with the share of plants using generator as the main electricity source in a year (column 1), or the same quantity computed at the province-year level (column 2).⁴⁶ We take both interaction variables as (inverse) proxies of grid quality. We find that the mechanism of machine turnover is muted when generators' usage is higher, consistently with the idea that there is less incentive to invest in electric machinery if grid quality is low.

Column 3 of Table A5 shows the results for Mexico. In the case of Mexico, we do not have similar information to compute the share of plants using a generator as their main source of electricity. Therefore, we rely on a new breakdown in the value of assets, which was included for the first time in the 2019 Economic Census. This variable indicates whether the plant holds assets for the generation of electricity. We calculated the share of firms (weighted by their size in terms of revenues) with a generator at the municipality-6-digits NAICS sector. We implicitly assume that this proportion hasn't changed over time.⁴⁷ The coefficient of the interaction between fuel prices and the municipality-NAICS 6-digits sector is not statistically significant, but very close to being so (estimated coefficient = -0.325, se = 0.2). Still, the negative coefficient observed is consistent with the result for Indonesia.⁴⁸

Additional support to the hypothesis that more productive technology is embodied in electric vintages of capital is provided by Table A6 in the appendix. The table shows the difference in performance among similar plants, as a function of their electricity consumption. Within narrowly defined industries, we construct an "electricity consumption gap", defined as the difference between a plant's share of electricity consumption and that of the plant with the highest share in industry. As we want to compare plants, we do not include plant fixed effect. To ensure maximum comparability, we control for age, size and narrowly-defined industry

⁴⁶We flag generator usage as main source of electricity when expenditure on fuel for electricity generation is higher than expenditure of grid electricity.

⁴⁷This definition is somewhat different from the one we use for Indonesia, as we do not directly observe yearly expenditure on fuels for generator use.

⁴⁸A potential explanation for this weaker result for Mexico is the impossibility of distinguishing whether the generator is the main energy source.

fixed effects (3 digits for Mexico, 5 digits for Indonesia). For Indonesia, it is also possible to include province dummies. To avoid potentially confounding effects, we fix the gap to the value of the first available observation for each plant. The table shows that plants with larger electricity gaps exhibit worse performance across the different measures, except for the TFPR specification for Mexico, where the electricity gap coefficient is negative but not significant at conventional levels.⁴⁹

A further possible implication of the results in Table 3 is that fuel price hikes would tend to reallocate output towards plants which have more room to upgrade their machinery. A reasonable hypothesis is that two such types of plants are older ones and those that produce lower quality products (proxied by lower mark-up), as they tend to have less technologically advanced production. To test for these hypotheses we separately interact age and mark-up with the fuel price variable. The results, available upon request, confirm the intuition.

Taken together, these results support the idea that an increase in fuel prices triggers technology upgrading in plants operating old vintages of fuel-powered capital. If that were indeed the case, then the impact of fuel prices on technological upgrading should be more muted for plants which are more likely to operate the latest capital vintages. Three characteristics of plants which are associated with the use of frontier technology are electricity intensity, foreign ownership (Blackman and Wu, 1999; Guadalupe et al., 2012; Brucal et al., 2018) and exporting status (Bustos, 2011; De Loecker, 2013). This hypothesis is confirmed in columns 1, 2 and 3 of Table 4, which show that in both countries machinery turnover is less responsive to fuel price hikes among electricity-intensive plants, among foreign plants, and among exporters.⁵⁰

While the main results are similar in both countries, the positive effect of fuel price hikes on performance is slightly larger for Indonesian plants. In light of the mechanism discussed above this difference is consistent with the hypothesis that Indonesian manufacturing plants may use more inefficient fuel-powered capital

⁴⁹One possible reason as to why the coefficients for Mexico are less precisely estimated is that we are comparing plants within 3 digits industries, which might still be very heterogeneous.

⁵⁰We use the following definitions to identify these plants: electricity-intensive plants have a share of energy consumption exceeding the 75th percentile of the distribution within each sector and year; foreign plants have over 95% foreign capital; exporters simply export at least some of their production. With different definitions the coefficients are less precisely estimated, although the signs remain consistent with our interpretation.

equipment than their Mexican counterparts. As a result the productivity boost from changing capital equipment is greater in Indonesia. At the same time the negative effect of electricity price increases on performance is more muted in Indonesia. This result is consistent with Indonesian plants using electricity-powered capital less efficiently than Mexican plants, thus having more room to adjust to electricity price increases.

These hypotheses that Mexican manufacturers may use more efficient and modern capital equipment than their Indonesian counterparts would deserve further scrutiny. However they appear also in line with the relative competitiveness of manufacturing industries in the two countries. At over US\$ 360 billion, Mexico's manufacturing exports in 2018 were 4.5 times larger than Indonesia's, despite a population less than half that of Indonesia.

6 Conclusion

Most of the literature on energy prices and plants' performance has focused on electricity. However, distinguishing between electricity and fuels is important because they power capital equipment of different types. In this paper, we test for the impact of both electricity and fuel prices, finding an asymmetric impact: fuel price increases have a positive effect on plants' performance while electricity price hikes worsen performance in Mexico and have a more muted effect in Indonesia. We contend that this result is consistent with fuel powering old technology capital vintages, while new technology tends to be embodied in electric capital vintages. An increase in fuel prices induces plants to scrap old fuel-powered machinery and purchase new electric equipment. Since electric machinery is more productive and energy-efficient, the static negative effect of fuel price increases is more than compensated by the positive effect on technological upgrading, with a potentially positive net effect on performance.

Our analysis is based on large nationally representative samples of manufacturing plants in two of the largest developing countries (Indonesia and Mexico). As such, threats to external validity which typically affects single country empirical analyses are less of a concern in our framework. Our approach also implies that the results are not specific to a particular setting or identification strategy.

These results suggest that besides the environmental and fiscal costs, subsidization of fuel prices may also lead to firms using sub-optimal technologies to the extent that a decrease in subsidy may actually improve performance. This reinforces the arguments in favor of fuel subsidy reform and carbon taxes, particularly in developing countries.

Our results are in line with the strong version of the Porter Hypothesis. An increase in fuel prices not only induce technological upgrading and higher productivity, but also higher profitability. Therefore, much as in the case of other technologies such as management practices (Bloom et al., 2013), the findings hint at some (information or otherwise) frictions that prevent firms from adopting more efficient electricity powered technology despite the positive returns of adoption. This calls for further research on the barriers to adoption in developing countries, which is needed to inform policy intervention in this area.

Finally, while the results confirm the negative impact of electricity prices on manufacturing performance, they do not necessarily support the policy of subsidization of electricity prices, which to different degrees Indonesia and Mexico employ. First, the production of electricity is also associated with negative environmental externalities as it still relies on fossil fuels for the most part.⁵¹ Second, the opportunity cost of the subsidy is high in countries with large needs for productive public investments, including in infrastructure and human capital. Third, subsidizing electricity prices would result in over-consumption of electricity, which may put the supply under strain, contributing to costly blackouts and brownouts. In the case of Indonesia, these factors are further compounded by the weak evidence that lower electricity prices may provide a boost to manufacturing performance.

⁵¹In the case of Indonesia for instance, around 60 percent of electricity generation is based on coal, benefiting from the policy of subsidization of coal price for electricity production.

References

- Abeberese, A. B. (2017). Electricity cost and firm performance: Evidence from India. *Review of Economics and Statistics*, 99(5):839–852.
- Acemoglu, D. (2010). When does labor scarcity encourage innovation? *Journal of Political Economy*, 118(6):1037–1078.
- Akerberg, D. A., Caves, K., and Frazer, G. (2015). Identification properties of recent production function estimators. *Econometrica*, 83(6):2411–2451.
- Allcott, H., Collard-Wexler, A., and O’Connell, S. D. (2016). How do electricity shortages affect industry? Evidence from India. *American Economic Review*, 106(3):587–624.
- Amiti, M. and Konings, J. (2007). Trade liberalization, intermediate inputs, and productivity: Evidence from Indonesia. *American Economic Review*, 97(5):1611–1638.
- Anderson, S. T. and Newell, R. G. (2004). Information programs for technology adoption: the case of energy-efficiency audits. *Resource and Energy Economics*, 26(1):27–50.
- Arlinghaus, J. and Van Dender, K. (2017). The environmental tax and subsidy reform in Mexico. *OECD*.
- Arnold, J. M. and Javorcik, B. S. (2009). Gifted kids or pushy parents? Foreign Direct Investment and plant productivity in Indonesia. *Journal of International Economics*, 79(1):42–53.
- Aw, B. Y., Chen, X., and Roberts, M. J. (2001). Firm-level evidence on productivity differentials and turnover in taiwanese manufacturing. *Journal of Development Economics*, 66(1):51–86.
- Beylis, G. and Cunha, B. (2017). *Energy Pricing Policies for Inclusive Growth in Latin America and the Caribbean*. The World Bank.

- Blackman, A. and Wu, X. (1999). Foreign Direct Investment in China's power sector: trends, benefits and barriers. *Energy policy*, 27(12):695–711.
- Bloom, N., Eifert, B., Mahajan, A., McKenzie, D., and Roberts, J. (2013). Does management matter? Evidence from India. *The Quarterly Journal of Economics*, 128(1):1–51.
- Brucal, A., Love, I., Javorcik, B., et al. (2018). Energy savings through foreign acquisitions? Evidence from Indonesian manufacturing plants. *Centre for Climate Change Economics and Policy Working Paper*, 324.
- Bustos, P. (2011). Trade liberalization, exports, and technology upgrading: Evidence on the impact of mercosur on argentinian firms. *American Economic Review*, 101(1):304–340.
- Cantore, N., Calì, M., and te Velde, D. W. (2016). Does energy efficiency improve technological change and economic growth in developing countries? *Energy Policy*, 92:279–285.
- Coady, D., Parry, I. W., Sears, L., and Shang, B. (2015). *How large are global energy subsidies?* Number 15-105. International Monetary Fund.
- De Loecker, J. (2013). Detecting learning by exporting. *American Economic Journal: Microeconomics*, 5(3):1–21.
- De Loecker, J., Goldberg, P. K., Khandelwal, A. K., and Pavcnik, N. (2016). Prices, markups, and trade reform. *Econometrica*, 84(2):445–510.
- DeCanio, S. J. (1993). Barriers within firms to energy-efficient investments. *Energy policy*, 21(9):906–914.
- DeCanio, S. J. and Watkins, W. E. (1998). Investment in energy efficiency: do the characteristics of firms matter? *Review of economics and Statistics*, 80(1):95–107.
- Delgado, M. A., Farinas, J. C., and Ruano, S. (2002). Firm productivity and export markets: a non-parametric approach. *Journal of international Economics*, 57(2):397–422.

- Deloitte (2020). Electrification in industrials: transitioning to a lower carbon future through electrification of industrial processes, spaces and fleets.
- EPRI (2007). Efficient electric technologies for industrial heating, emerging activities. <https://www.epri.com>.
- Foster, L., Haltiwanger, J., and Syverson, C. (2008). Reallocation, firm turnover, and efficiency: Selection on productivity or profitability? *American Economic Review*, 98(1):394–425.
- Fried, S. and Lagakos, D. (2019). Cottage industry to factories? the effects of electrification on the macroeconomy. Paper presented at the 2019 AEA meeting in Atlanta.
- Guadalupe, M., Kuzmina, O., and Thomas, C. (2012). Innovation and foreign ownership. *American Economic Review*, 102(7):3594–3627.
- IEA (2014). Energy supply security ? Indonesia. International Energy Agency, Paris.
- IEA (2015). Indonesia 2015 - Energy policy beyond IEA countries. International Energy Agency, Paris.
- Inchauste, G. and Victor, D. G. (2017). *The political economy of energy subsidy reform*. The World Bank.
- Javorcik, B. and Poelhekke, S. (2017). Former foreign affiliates: Cast out and outperformed? *Journal of the European Economic Association*, 15(3):501–539.
- Kassem, D. (2019). What happens when the grid arrives? Paper presented at the 2019 AEA meeting in Atlanta.
- Malek, M. A. (2005). *Power Boiler Design, Inspection, and Repair: Per ASME Boiler and Pressure*. McGraw Hill Professional.
- Marin, G. and Vona, F. (2017). The impact of energy prices on employment and environmental performance: Evidence from French manufacturing establishments.

- McKinsey (2020). Plugging in: what electrification can do for industry.
- McKinsey, G. (2009). Pathways to a low-carbon economy. Version 2 of the Global Greenhouse Gas Abatement Cost Curve. *McKinsey & Company, Stockholm*.
- Olley, G. S. and Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, 64(6):1263.
- Pavcnik, N. (2002). Trade liberalization, exit, and productivity improvements: Evidence from Chilean plants. *The Review of Economic Studies*, 69(1):245–276.
- Popp, D. (2002). Induced innovation and energy prices. *American Economic Review*, 92(1):160–180.
- Porter, M. E. and Van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives*, 9(4):97–118.
- Poterba, J. M. and Summers, L. H. (1995). A CEO survey of US companies’ time horizons and hurdle rates. *MIT Sloan Management Review*, 37(1):43.
- Pye, M. and McKane, A. (2000). Making a stronger case for industrial energy efficiency by quantifying non-energy benefits. *Resources, Conservation and Recycling*, 28(3-4):171–183.
- Rentschler, J. and Kornejew, M. (2018). Energy price variation and competitiveness: Firm level evidence from Indonesia. In *Fossil Fuel Subsidy Reforms*, pages 75–106. Routledge.
- Rentschler, J., Kornejew, M., and Bazilian, M. (2017). Fossil fuel subsidy reforms and their impacts on firms. *Energy Policy*, 108:617–623.
- Ryan, N. (2018). Energy productivity and energy demand: Experimental evidence from Indian manufacturing plants. No. w24619, National Bureau of Economic Research.
- Topalova, P. and Khandelwal, A. (2011). Trade liberalization and firm productivity: The case of India. *Review of Economics and Statistics*, 93(3):995–1009.

- Worrell, E., Laitner, J., Ruth, M., and Finman, H. (2003). Productivity benefits of industrial energy efficiency measures. *Energy*, 28(11):1081–1098.
- Xepapadeas, A. and de Zeeuw, A. (1999). Environmental policy and competitiveness: the porter hypothesis and the composition of capital. *Journal of Environmental Economics and Management*, 37(2):165–182.

7 Tables

Table 1: First stage regression

	(1)	(2)	(3)	(4)
	ln(Price electricity)		ln(Price fuels)	
	MEX	IDN	MEX	IDN
IV price electricity	0.9936*** (0.0015)	0.979*** (0.010)	-0.3141*** (0.0803)	0.010 (0.007)
IV price fuels	-0.0002 (0.0002)	0.035* (0.020)	0.2898*** (0.0204)	1.023*** (0.022)
Controls				
Plant fixed effects	Yes	Yes	Yes	Yes
Sector-time effects	Yes	Yes	Yes	Yes
Region-time effects	Yes	Yes	Yes	Yes
Observations	42,152	240,114	42,152	240,114
Number of plants	7,551	28,755	7,551	28,755

* Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level. Robust standard errors in parentheses.

*Note: The results of the first stage for Mexico are based on the sample for column (5) in Table 2. Using the samples from other specifications do not change the results. *Source:* Authors' calculations using data from EAIM and EMIM, INEGI (Mexico), and Statistik Industri (Indonesia).

Table 2: Impact of energy prices on performance - 2SLS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ln(TFPR)		ln(VA/L)		ln(net profits)		ln(VA/KWh)	
	MEX	IDN	MEX	IDN	MEX	IDN	MEX	IDN
ln(Price fuels)	0.136*** (0.0163)	0.163*** (0.030)	0.244*** (0.0330)	0.179*** (0.042)	1.407*** (0.439)	1.825*** (0.207)	0.222*** (0.0359)	0.670*** (0.066)
ln(Price electricity)	-0.411*** (0.0317)	-0.032** (0.015)	-0.245*** (0.0562)	0.013 (0.025)	-2.972*** (0.232)	-0.459*** (0.101)	1.167*** (0.0814)	0.332*** (0.036)
Controls								
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector-time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region-time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	37,413	177,469	40,826	238,549	42,152	238,549	39,992	236,699
Number of plants	6,449	24,057	7,467	27,191	7,551	27,191	7,321	27,175
First stage F	129.6	1018.8	136.6	1658	141.9	1661	156.2	1623

* Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level. Robust standard errors in parentheses.
Note: The number of observations for Mexico differs across specifications due to missing values in some of the variables used to construct the dependent variables.
Robustness tests were conducted, restricting the sample to the same number of observations, and the results (available upon request) did not change.
Net profits are defined as Value Added minus total wages paid and capital expenditure.
Source: Authors' calculations using data from EAIM and EMIM, INEGI (Mexico), and Statistik Industri (Indonesia).

Table 3: Machinery turnover, electricity/fuel intensity of capital, and technical efficiency

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Machine turnover		ln(qElec/K)		ln(qFuels/K)		ln(TFPQ)	
	MEX	IDN	MEX	IDN	MEX	IDN	MEX	IDN
ln(Price fuels)	0.356* (0.212)	0.290** (0.130)	0.226** (0.0981)	0.211** (0.090)	-0.190* (-1.74)	-0.458*** (0.096)	0.358* (0.192)	0.093** (0.039)
ln(Price electricity)	-2.192*** (0.283)	-0.186*** (0.071)	-2.322*** (0.137)	-0.973*** (0.061)	-0.186*** (-5.93)	0.018 (0.043)	0.0590 (0.0639)	-0.015 (0.013)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector-time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region-time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	31,587	237,936	30,333	170,897	37,978	176,74	24,319	166,063
Number of plants	5,468	27,169	5,270	24,356	6,260	24,176	4,505	23,311
First stage F	62.47	1615	63.08	881.5	76,701	848.9	30.99	960.4

Machine turnover is the log of the sum of purchase and sales of machinery and equipment. * Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level. Robust standard errors in parentheses.
Source: Authors' calculations using data from EAIM and EMIM, INEGI (Mexico), and Statistik Industri (Indonesia).

Table 4: Machinery turnover in electricity-intensive, foreign and exporting plants

	(1)	(2)	(3)	(4)	(5)	(6)
	Machine turnover		Machine turnover		Machine turnover	
	frontier: ELECTR.-INTENSIVE		frontier: FOREIGN		frontier: EXPORTER	
	MEX	IDN	MEX	IDN	MEX	IDN
ln(Price fuels)	0.392* (0.217)	0.423*** (0.148)	0.795*** (0.306)	0.322** (0.133)	0.876* (0.50)	0.394*** (0.136)
frontier*ln(Price fuels)	-0.108 (0.140)	-0.350* (0.186)	-0.620*** (0.205)	-1.375* (0.785)	-0.588 (0.384)	-0.565** (0.255)
ln(Price electricity)	-2.295*** (0.300)	-0.199** (0.092)	-2.017*** (0.299)	-0.214*** (0.072)	-2.010*** (0.327)	-0.213*** (0.076)
frontier*ln(Price electricity)	0.393 (0.325)	0.058 (0.121)	-0.677 (0.430)	0.946 (0.664)	-0.477 (0.451)	0.154 (0.175)
Controls						
Plant fixed effects	yes	yes	Yes	Yes	Yes	Yes
Sector-time effects	yes	yes	Yes	Yes	Yes	Yes
Region-time effects	yes	yes	Yes	Yes	Yes	Yes
First stage F	31.55	629.6	28.19	35.14	55.87	148.7
Observations	31,197	237,936	31,587	235,735	31,587	237,936
Number of plants	5,357	27,169	5,468	26,847	5,468	27,169

Machine turnover is the log of the sum of purchase and sales of machinery and equipment. * Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level. Robust standard errors in parentheses.

Source: Authors' calculations using data from EAIM and EMIM, INEGI (Mexico), and Statistik Industri (Indonesia).

Table A1: Summary statistics

Variables	(1) N	(2) Mean	(3) SD	(4) Min	(5) Max
Indonesia					
Real raw materials (Rp. '000)	275,393	84,359	226,242	0.00855	6,333,000
Price electricity (Rp. '000/KWh)	278,341	1.094	0.951	0.0175	10
Price fuels (Rp. '000/KWh)	277,000	0.531	0.492	0.0333	9.818
Real VA/L (Rp. '000)	285,708	552.4	1,369	0.0163	113,016
Real VA/Energy (Rp. '000/KWh)	281,861	1.987	151.8	0.0000025	65,818
Real wage bill (Rp. '000)	285,616	15,109	87,608	0.0817	30,040,000
Profitability (profit/sales)	282,851	0.226	0.211	-1.293	0.998
Real sales + purchase of machinery (Rp. '000)	284,315	1,148,000	140,500,000	0	56,490,000,000
Electricity/K (KWh)	198,573	0.0835	0.376	0.00000006	35.17
Fuels/K (KWh)	206,244	0.177	0.828	0.00000017	72.40
Real capital stock (Rp. '000)	234,042	8,272,000	72,290,000	12,544	16,970,000,000
TFPR	187,610	-0.175	0.558	-2.036	1.795
TFPQ	201,330	1.836	7.515	0.00978	297.5
Mexico					
Real raw materials ('000 MXP)	30,857	152,297	425,155	0	3,204,225
Price electricity (MXP/KWh)	42,601	1.501	0.319	0.814	2.140
Price fuels (MXP/KWh)	38,180	0.186	0.123	0	0.685
Real VA/L (MXP)	41,321	389,480	708,170	11,331	5,837,421
Real VA/Energy (MXP/KWh)	40,485	0.511	21.797	0	3,328
Real wage bill ('000 MXP)	30,856	32,020	69,457	0	471,003
Profitability (profit/sales)	42,601	0.190	0.178	-0.363	0.727
Real sales + purchases of machinery ('000 MXP)	31,857	8,311	27,568	0	212,013
Electricity/K (KWh per '000 MXP)	30,597	0.377	1.106	0.002	8.436
Fuels/K (KWh per '000 MXP)	38,187	2.390	4.138	0	31.712
Real capital stock ('000 MXP)	30,857	88,282	245,258	0	1,920,510
TFPR index	38,088	0.660	0.452	-1.324	1.778
TFPQ index	23,146	2.009	2.132	0.121	10.713

All variables are expressed in their original units.

Source: Authors' calculations using data from Statistik Industri, BPS (Indonesia) and EAIM and EMIM, INEGI (Mexico).

Notes: All price variables (raw materials, electricity, fuels, value added, wage bill, profit, machinery sale and purchase, capital stock) are expressed in thousand Indonesian Rupiah 2010 (for Indonesia) or Mexican Pesos of 2012 (for Mexico). Energy consumption variables (for both electricity and fuels) are expressed in KWh equivalent. Profitability is measured as operating profits (value added minus wages and salaries) normalized by sales.

Table A2: Impact of energy prices on performance - OLS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ln(TFPR)		ln(VA/L)		ln(net profits)		ln(VA/KWh)	
	MEX	IDN	MEX	IDN	MEX	IDN	MEX	IDN
ln(Price fuels)	0.003* (0.002)	0.104*** (0.006)	0.000358 (0.00361)	0.215*** (0.009)	0.002 (0.027)	0.022*** (0.002)	-0.00336 (0.00423)	0.399*** (0.008)
ln(Price electricity)	-0.569*** (0.030)	0.161*** (0.004)	-0.261*** (0.0537)	0.380*** (0.006)	-5.489*** (0.336)	0.023*** (0.001)	1.142*** (0.0790)	0.528*** (0.015)
Controls								
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector-time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region-time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	37,413	179,654	40,826	240,113	42,152	237,618	39,992	238,273
Number of plants	6,449	26,242	7,467	28,755	7,551	28,739	7,321	28,749

* Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level. Robust standard errors in parentheses.

Note: The number of observations for Mexico differs across specifications due to missing values in some of the variables used to construct the dependent variables. Robustness tests were conducted, restricting the sample to the same number of observations, and the results (available upon request) did not change.

Net profits are defined as Value Added minus total wages paid and capital expenditure.

Source: Authors' calculations using data from EAIM and EMIM, INEGI (Mexico), and Statistik Industri (Indonesia).

Table A3: Impact of energy prices on performance: restricted sample for Indonesia (2009-2015)

	(1)	(2)	(3)	(4)
	ln(TFPR)	ln(VA/L)	Profitability	ln(VA/KWh)
ln(Price fuels)	0.212*** (0.057)	0.283*** (0.079)	0.160*** (0.024)	0.376*** (0.123)
ln(Price electricity)	0.037 (0.026)	-0.077 (0.050)	0.013 (0.011)	0.185*** (0.069)
Controls				
Plant fixed effects	Yes	Yes	Yes	Yes
Sector-time effects	Yes	Yes	Yes	Yes
Region-time effects	Yes	Yes	Yes	Yes
Observations	70,972	97,509	95,431	96,689
Number of Plants	14,223	17,45	17,437	17,42
First Stage F	425.4	737.8	746.3	730.1

* Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level. Robust standard errors in parentheses.

Source: Authors' calculations using data from Statistik Industri (Indonesia).

Table A4: Placebo experiment for impact of energy prices on other categories of assets

	(1) ln(purchases + sales) buildings	(2) ln(purchases + sales) vehicles	(3) ln(purchases + sales) land	(4) ln(purchases + sales) land	(5) ln(purchases + sales) land
ln(Price fuels)	IDN 0.152 (0.120)	MEX 0.261 (0.189)	IDN 0.316*** (0.116)	MEX -0.0413 (0.182)	IDN 0.130 (0.095)
ln(Price electricity)	-0.040 (0.066)	-1.032*** (0.225)	-0.088 (0.068)	-0.719*** (0.214)	0.024 (0.051)
Plant fixed effects	Yes	Yes	Yes	Yes	Yes
Sector-time effects	Yes	Yes	Yes	Yes	Yes
Region-time effects	Yes	Yes	Yes	Yes	Yes
Observations	237,936	30,809	237,936	30,802	237,913
Number of plants	27,169	5,317	27,169	5,270	27,169
First stage F	1615	58.93	1615	58.96	1614

* Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level. Robust standard errors in parentheses.

*For Mexico we do not have data on land, just vehicles and buildings. *Source:* Authors' calculations using data from EAIM and EMIM, INEGI (Mexico), and Statistik Industri (Indonesia).

Table A5: Machinery turnover and grid quality

	(1)	(2)	(3)
	Machine turnover	Machine turnover	Machine turnover
ln(Price electricity)	-0.157** (0.074)	-0.145* (0.075)	-2.085*** (0.194)
ln(Price fuels)	2.927** (1.402)	2.023*** (0.719)	0.318* (0.182)
ln(Fuel price)* yearly share of plants using generator as the main source	-16.829* (9.016)		
ln(Fuel price)* province-year share of plants using generator as the main source		-24.845** (10.389)	
ln(Fuel price)* municipality-sector share of plants using generator			-0.325 (0.200)
Observations	237,936	237,936	40,432
Number of PSID	27,169	27,169	7,221
Plant FE	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes
Region-year FE	Yes	Yes	Yes
Log province real GDP	Yes	Yes	No
First Stage F	107.3	134.3	156.564

Machine turnover is the log of the sum of purchase and sales of machinery and equipment. * Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level. Robust standard errors in parentheses.

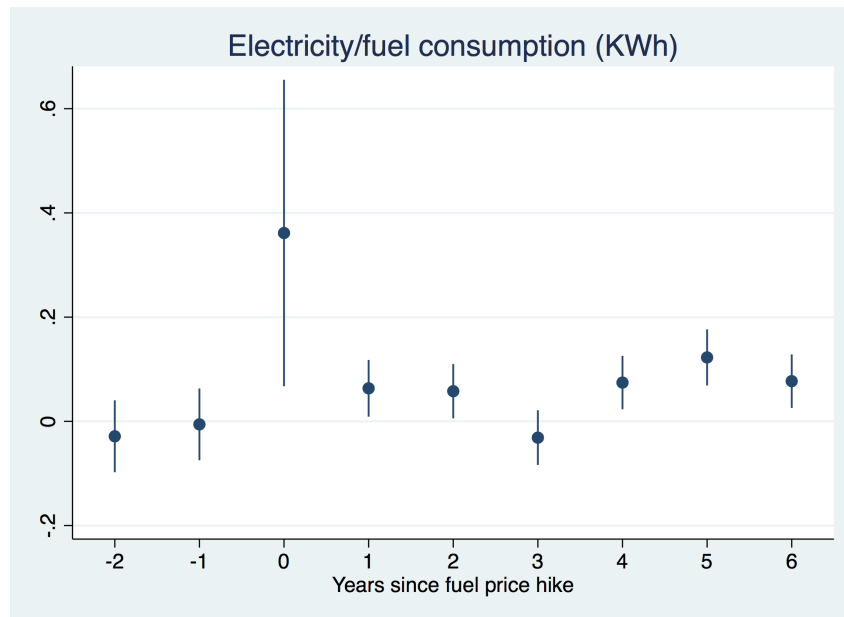
Source: Authors' calculations using data from EAIM and EMIM, INEGI (Mexico), and Statistik Industri (Indonesia).

Table A6: Comparison electricity-intensive plants vs others

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ln(TFPR)		ln(VA/worker)		ln(net profits)		ln(VA/KWh)	
	MEX	IDN	MEX	IDN	MEX	IDN	MEX	IDN
Electricity gap	-0.0285 (0.0241)	-0.002* (0.001)	-0.0830* (0.043)	-0.016*** (0.001)	-0.168* (0.102)	-0.005*** (0.000)	-0.253*** (0.0502)	-0.193*** (0.002)
Controls								
Plant fixed effects	No	No	No	No	No	No	No	No
Sector-time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region-time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age and size	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	29,224	190,754	47,657	246,302	49,128	243,71	47,370	243,972

* Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level. Robust standard errors in parentheses.
Source: Authors' calculations using data from EAIM and EMIM, INEGI (Mexico), and Statistik Industri (Indonesia).

Figure A1: Impact of leads and lags of fuel prices

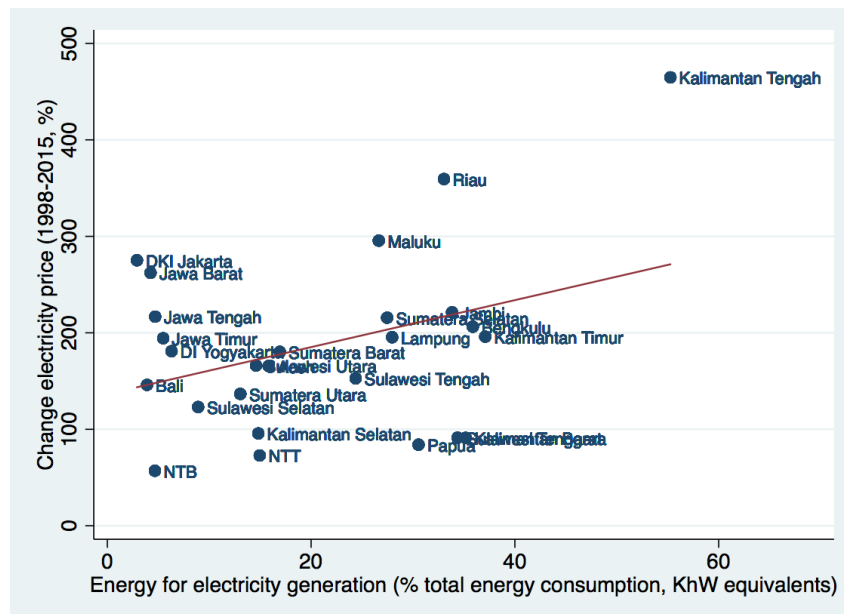


Note: The figure shows estimates of the impact of fuel prices on KWh of electricity consumption over KWh equivalents of fossil fuels (in logs). We estimate the coefficients instrumenting the contemporaneous values of fuel and electricity prices, while assuming that all leads and lags are exogenous. The bars around each point represent 95% confidence intervals. The figure is based on the Indonesian sample.

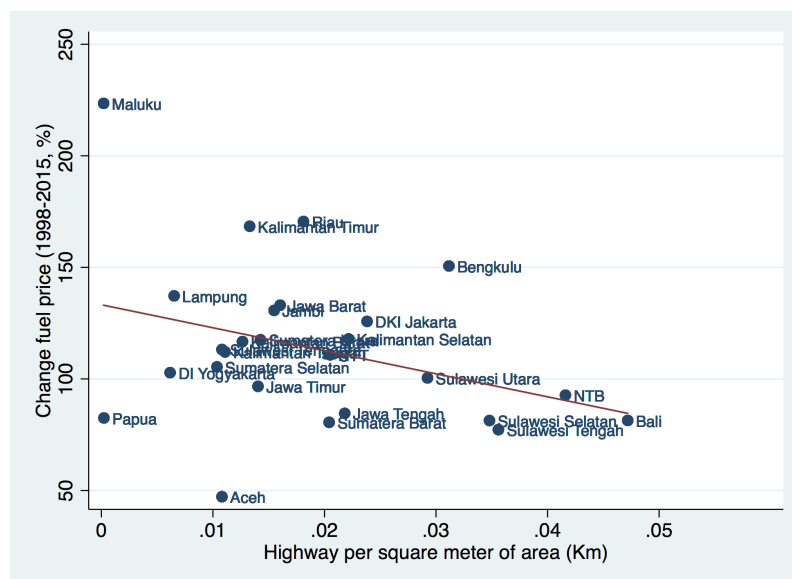
Source: Authors' calculations with data from SI (Indonesia).

Figure A2: Changes in energy prices and infrastructure levels across Indonesian provinces

(a) Electricity prices and self-generation of through generator



(b) Growth in fuel prices and road infrastructure development



Note: Electricity prices include PNL and non-PNL electricity purchased from the grid. Fuel prices refer to gasoline, diesel and lubricants. Individual energy types are aggregated in the two categories by using their consumption shares for each plant. Energy prices are expressed in real terms using two digits-industry price deflators. The variables on the X-axis are averaged over the 1998-2015 period.

Source: Authors' calculations with data from SI and World Bank.

A Construction of Indonesian Capital Series

In order to avoid relying on depreciation rates, we tried to preserve the self-reported original values by the plant as much as possible and applied the PIM only to fill gaps. In this paper self-reported capital series were object of an extensive cleaning algorithm aimed at mitigating measurement errors.⁵² Our algorithm consists first in replacing zero or negative values as missing observations and then applying a two-steps procedure based on capital-labor ratios (KL). For each year, we compute the average KL in each 4 digit KBLI sector over the whole sample, but excluding the years in which the average and total values of the capital stock exhibited suspicious jumps, i.e. 1996, 2000, 2003, 2006, 2009 and 2014. An observation is dropped if the ratio of plant-KL to the sector average KL is below 0.02 or larger than 50.⁵³ Then, in a second step we compare a plant KL in a given year with the average value of the KL within the same plant but in the other years of observation. An observation is dropped if the ratio of plant-year-KL to the plant average KL is below 0.2 or larger than 5. Plants are dropped from the sample in case the cleaning procedure results in all missing values of self-reported capital.

When a plant has some but not all valid observations for self-reported capital stock, then missing values are replaced by applying a forward/backward perpetual inventory method (PIM). Being only a fraction of the total observations, we rely less on estimates of depreciation rates.⁵⁴ Previous studies focus on the first year of observation of a plant, without assessing the plausibility of the data point. Since PIM series are very sensitive to the choice of the initial observation, especially with relatively short time series, the resulting capital stock could be severely mis-measured. Moreover, information on purchases and sales of capital equipment,

⁵²One important problem with the reported series is that in some years, there are plants were characterised by implausible large values of capital. Studying the behaviour of the stock within plants reveals that in some circumstances plants reported values in different units. The phenomenon is somewhat more frequent in 1996 and 2006, when the BPS conducted a wider economic census that collected information in units rather than in thousand Rupiah. For instance, in 2006 the number of surveyed firms increased by 40%. The increase in coverage required hiring unexperienced enumerators that were more likely to make mistakes, which contributed to increase measurement errors.

⁵³We experiment with stricter thresholds which result in too many observations dropped.

⁵⁴We follow Arnold and Javorcik (2009) and assume that the annual depreciation rate for buildings is 3.3 percent, for machinery 10 percent, and for vehicles and other fixed assets 20 percent. For land, we assumed no depreciation.

which is subject to the same measurement errors of the reported capital. For such a reason, after filling missing values with the PIM we re-apply the two stages check described above in order to minimise the possibility of mis-measurement. As a final test, we compute plant-level growth rates of KL and we check that it is reasonably distributed (Figure A3). Figure A4 compares original and clean capital stock series.

Figure A3: Plants' growth rate distribution of capital-labor ratio.

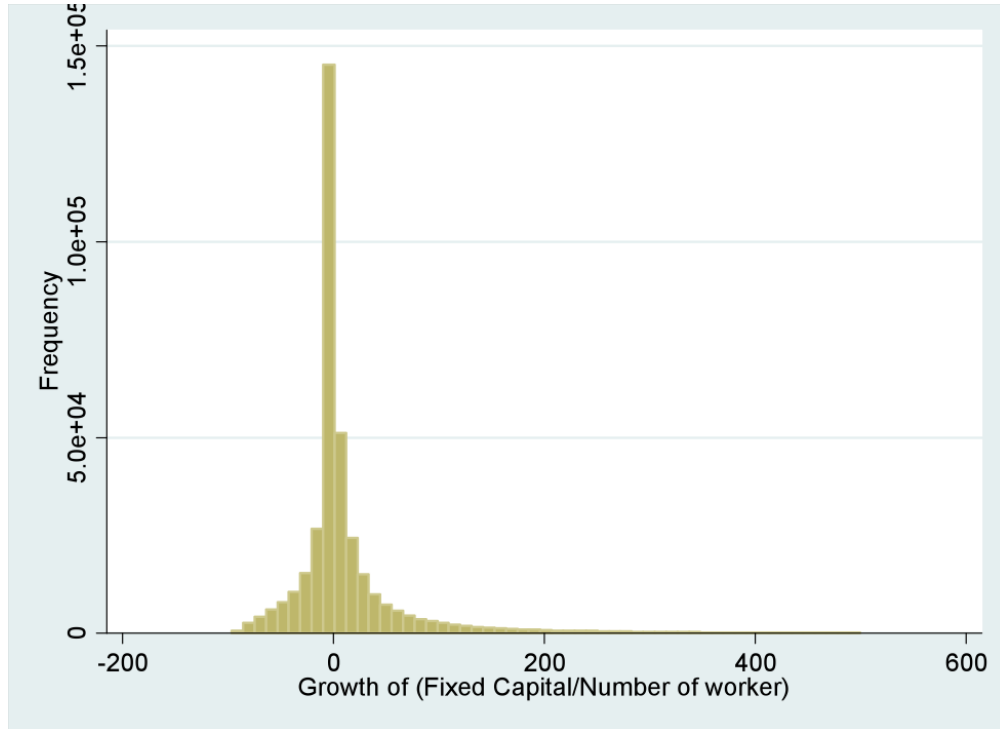


Figure A4: Comparison of Aggregate Nominal Capital Stock Series.

