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TOO MUCH ENERGY
THE PERVERSE EFFECT OF LOW FUEL PRICES ON FIRMS

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The Perverse Effect of Low Fuel Prices on Firms*

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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 3.3 percent increase in total factor productivity for Indonesia and 1.2 percent for Mexico. The evidence suggests that the effect is driven by the incentives that fuel price increases provide to plants towards switching away from fuel- towards 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

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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 fuel consumption is often subsidized.[1]

Mexico and Indonesia are cases in point. In 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).[2] Similarly, the Indonesian government removed much of the long-standing fuel subsidy from the national budget in 2015 so that by 2016 the subsidy had declined to 2.2% of central government's expenditures (from 13.5% in 2014).[3] However concerns similar to those of the Mexican case eventually led the government to reinstate part of the subsidy, which by 2018 accounted for 4.4% of central government's expenditures.[4]

This paper uses data from these two countries to provide novel evidence that increases in energy prices do not necessarily worsen the performance of manufacturing firms. 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

[1]Coady 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).

[2]Eventually a considerably less ambitious carbon tax was approved at the end of 2013, including the rule of capping the tax to a level which would not increase the fuels retail price by more than 3%.

[3]These figures are based on the audited Indonesian government expenditure reports.

[4]These types of concerns are illustrated for instance in a recent interview of a top bureaucrat in the Indonesian Ministry of Industry, who stated that it is important to maintain cheap fuel prices to ensure industrial development including downstream industries (Sulmaihati, 2019).

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. Abeberese, 2017; Allcott et al., 2016; Fried and Lagakos, 2019; Marin and Vona, 2017).[5] Distinguishing between energy sources is important as they power different types of capital equipment. 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).[6] 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 1.2% in Revenue Total Factor Productivity (TFPR) and a 0.4 percentage points increase in profitability; for Indonesia, a 10% increase in fuel prices raises productivity by 3.3% and profitability by almost one percentage point.

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, an increase in electricity consumption per unit of capital, in energy efficiency of production and in quantity TFP (TFPQ), a key measure of technical efficiency.[7] Thus, the switch towards electric machinery induced by fuel price hikes is a form of technological upgrading. 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 techno-

[5] Rentschler 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.

[6] This is consistent with our data and case studies from the engineering literature. Electric heating technologies are typically more energy-efficient and more productive than fuel-powered ones (EPRI, 2007).

[7] The 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.

logical 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). In fact this effect is more muted in Indonesia than Mexico, which supports the hypothesis that Indonesia's manufacturing industry may use electricity-powered capital less efficiently than Mexico's.

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 allow 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 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).

In 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. 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 has not received empirical support to date.[8] This lack of support is particularly salient given that the strong Porter hypothesis is also 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.[9]

However, 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.[10] 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 tech-

[8]Cantore 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.

[9]With market imperfections it is theoretically possible to have a positive link between factor prices and productivity. 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 a technology which "saves" on that factor, ultimately resulting in a increase of productivity. The theoretical model in Acemoglu (2010) is consistent with empirical evidence in Popp (2002), where higher energy prices lead to development of energy-saving technology.

[10]Pye 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.

nological opportunities might be particularly low in countries 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 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.[11] A 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 is available (panel a) in Figure 1).[12] 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

[11] The figure refers to 2014 according to World Bank Data on emissions.

[12] In 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.

b) in Figure 1).

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 Perusahan 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.[13]

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.[14] The large variation in energy distribution costs is well documented (IEA, 2015; Inchauste and Victor, 2017) and is confirmed in our data.

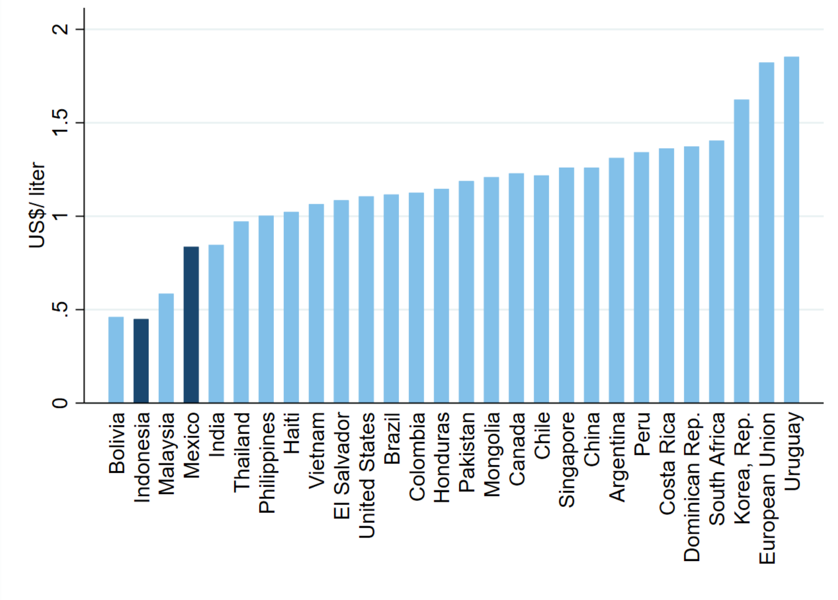
As shown in Figure 2, in real terms both electricity and fuel prices faced by manufacturing plants increased in a non-uniform way across the Indonesian archipelago in the period of analysis (1998-2015). The electricity price increase was particularly marked in central Kalimantan, in eastern Sumatra and 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

[13]Domestic refining covers just over 50 percent of the Indonesian gasoline and diesel markets

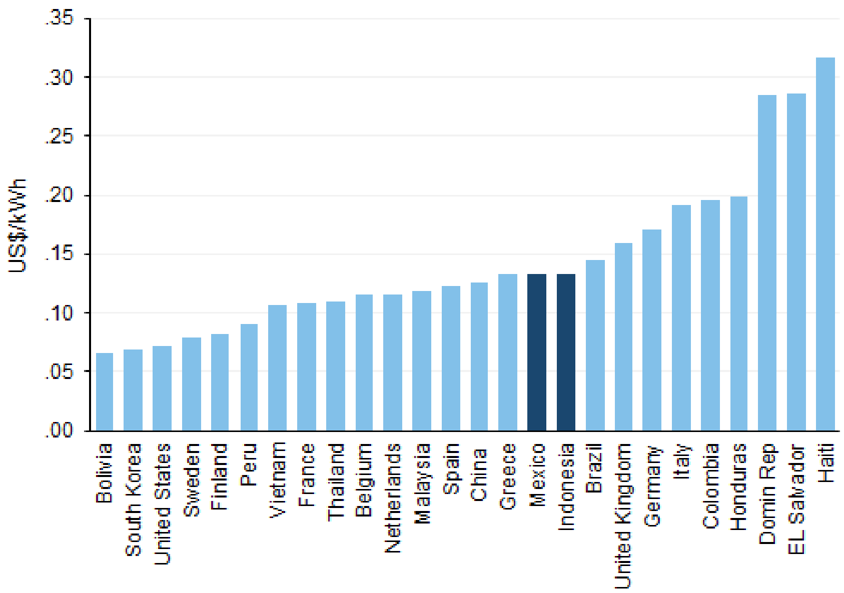
[14]While today Indonesia is divided into 33 provinces, we use the administrative division of provinces at the beginning of our period of analysis, when Indonesia was split into 27 provinces.

Figure 1: International comparison of Energy Prices

(a) Diesel prices



(b) Industrial electricity prices



Source: Beylis and Cunha (2017)

poses challenges for electricity distribution to keep up with heavy demand.[15] Figure A1 of 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 through 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.[16] 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 A1 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.

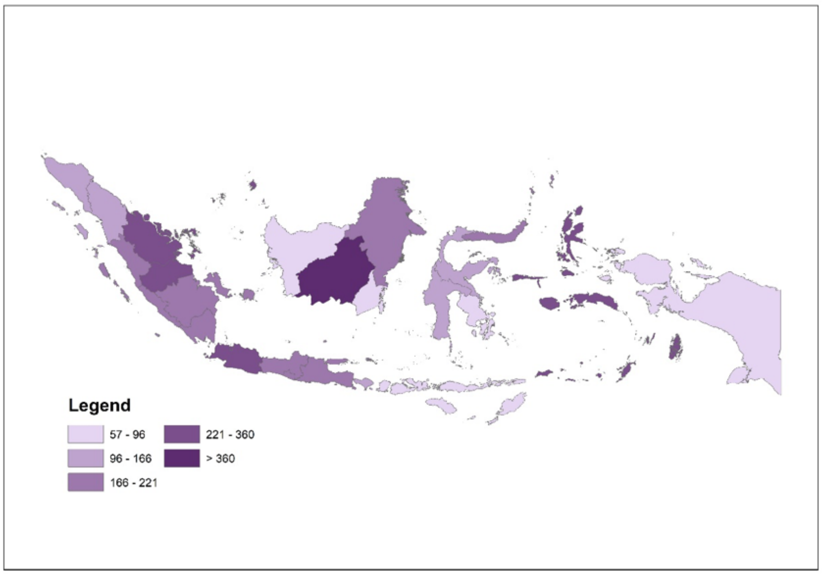
The empirical analysis will rely on such geographic variation of electricity and fuel prices over time to extract the exogenous local component of price changes over time.

[15] This 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.

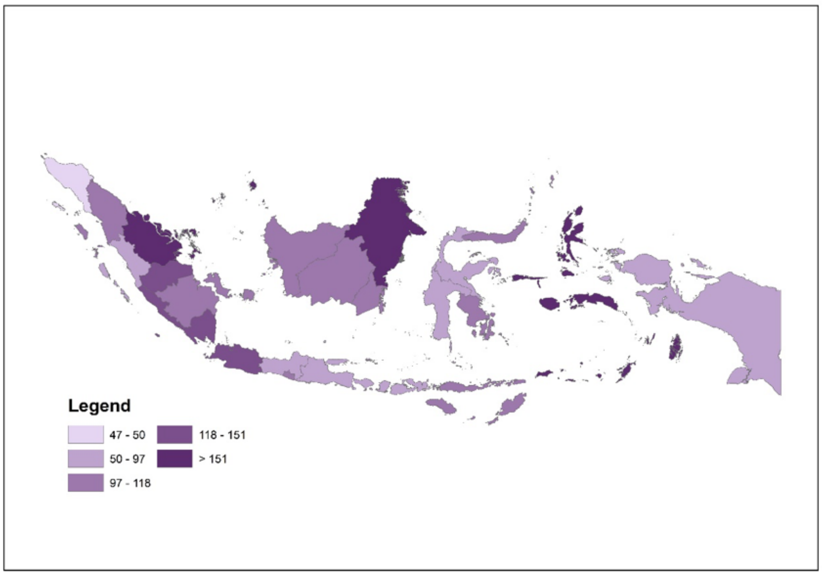
[16] In some cases, variation is induced by policy. For instance, frequent shortages have prompted authorities to approve higher tariffs in remote areas to unlock local small-scale supply from independent utilities (IEA, 2014). In an attempt to address these large price differences, in 2016 the Government 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

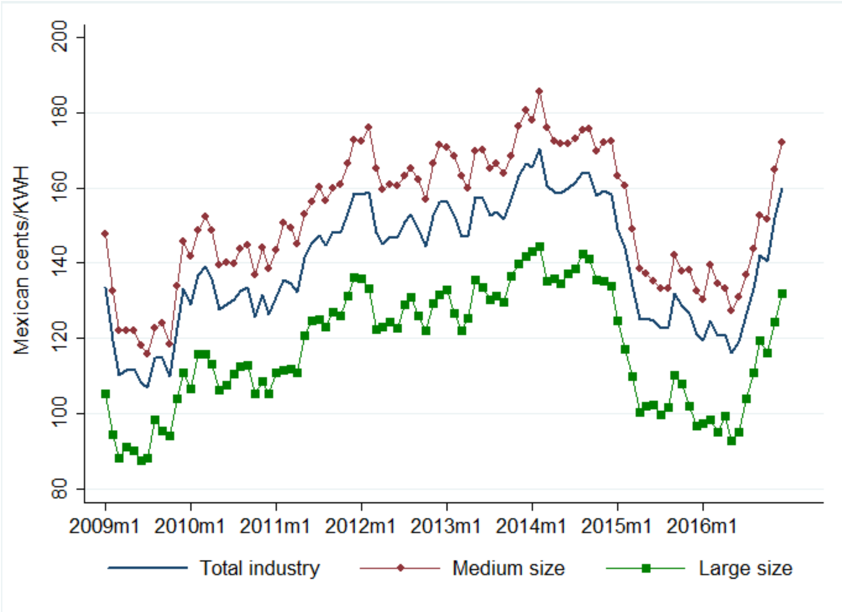
In Mexico, the Secretaría de Hacienda y Crédito Público (Ministry of Finance, abbreviated as SHCP) is the lead institution in setting prices for both electricity and fuels. SHCP sets electricity prices including the subsidization for agricultural and residential sectors. Mexico has a complex electricity 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.[17] 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. If we analyze mean prices for the four main tariffs that apply to medium and large firms (second panel of Figure 3), we observe that there is also substantial variation in prices. Firms in the level of transmission and very high-tension (HT) pay much lower average prices, while firms in the medium level of tension and high distribution face a much higher tariff. A factor worth mentioning in these graphs is that a significant drop in the price is observed in 2015, which 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 trying to

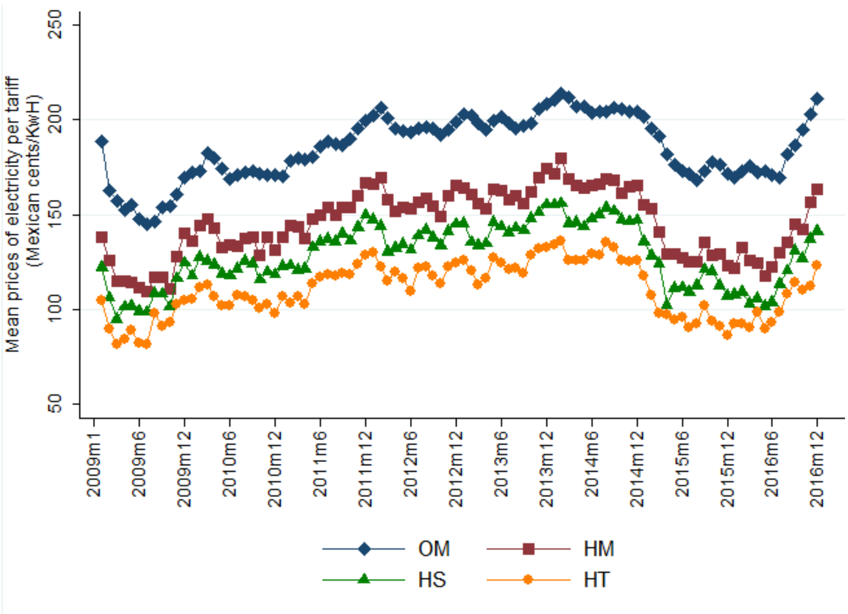
[17] For industrial and commercial users, tariffs are mainly set by tension lines used, hourly prices and the marginal costs of the Comisión Federal de Electricidad (Federal Electricity Commission, CFE) for providing the services.

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).

standardize them with those in the US 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.[18]

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 US. Later, with the development in Mexico of liquefied natural gas (LNG) facilities to import this fuel from other regions, price references from Gulf Coast and the West Coast of the United States have been also used.[19]

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.

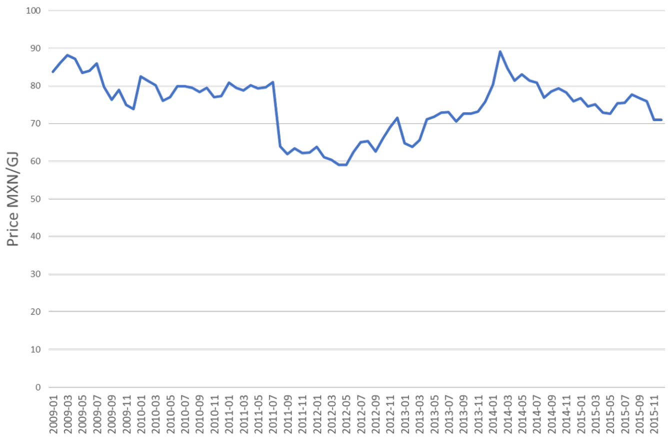
In Figure 4, we present the evolution of average fuel prices between 2009 and 2015. As depicted in the Figure, a drop in the average price occurred in 2010, following the trend observed in the international markets. Additionally, in 2015, there is a reduction in the average prices which is mainly driven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

[18]During 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.

[19]Currently, 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

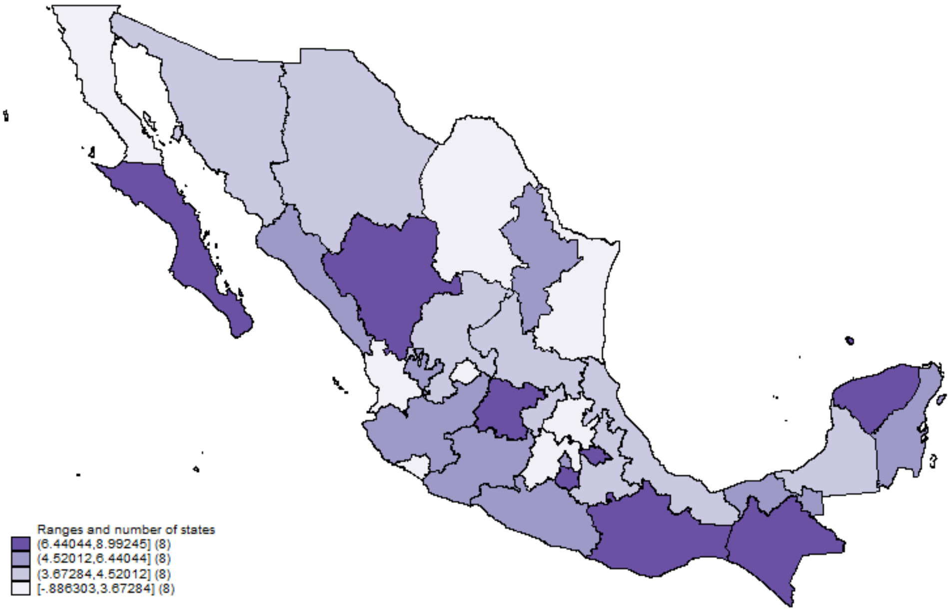


Note: Fuel prices are calculated as a weighted average of the prices of coal, petroleum coke, diesel and natural gas using 3-digits NAICS consumption as weights *Source:* Authors' calculations with data from SENER.

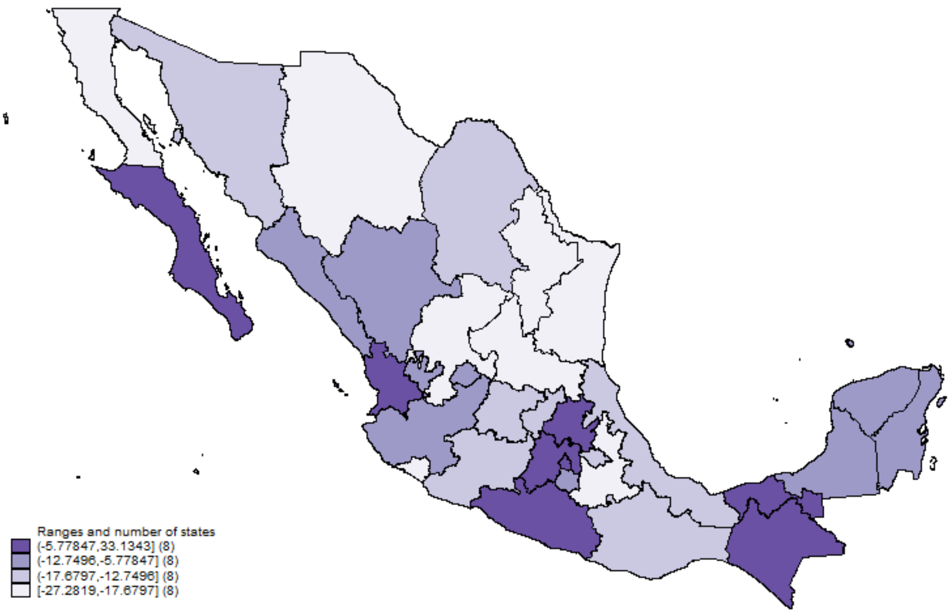
At the regional level, as shown in Figure 5, we observe that in real terms, electricity prices, weighted by the corresponding industrial tariff, increased more in states of the South-East, which further decreases the competitiveness of states that are already deprived in terms of development. Other states 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.

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.

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.

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.[20]

[20]To 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.

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.[21] Since the focus of this paper is on the distinction between fossil fuels and electricity, we categorise 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.[22] 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.[23]

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 this data is available, which is not necessarily accurate.[24] One potential advantage of using PIM is that purchase and sales data might be more accurate relative to self-reported value of the stock, requiring an appropriate calculation of market values and depreciations. However, PIM needs to rely on measures of capital depreciation, which are difficult to accurately estimate. To mitigate such tradeoff, we have adopted a hybrid strategy. We first clean the self-reported adopting an algorithm which keeps only observations that fulfill a battery of tests.[25] Then, we apply the PIM only to fill the gaps between

[21]The Indonesian survey asks manufacturers about expenditures and quantities of PLN and 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.

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

[23]A similar strategy can be found in Marin and Vona (2017).

[24]In 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.

[25]The procedure is described in the appendix.

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 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 establishments 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

To construct electricity prices, we combine EAIM information on plant-level electricity expenditure with state-level data on number of users, values and volumes of electricity sales, and state-month-specific electricity tariffs from the CFE. First, using the information on value and volume of consumption at the tariff-municipality-month level from Secretaría de Energía (Ministry of Energy, SENER), we calculated average tariffs paid as value over volume (pesos/KwH) and average sales as sales over number of users (pesos/user). Secondly, we analyzed this information and defined a lower and an upper limit of electricity bills for each municipality-tariff level. On the basis of these lower and upper limits, we assigned a tariff level to each establishment based on its expenditure on electricity. We assigned four different electricity tariffs (two for medium-sized companies and two for large companies). Once we defined the tariff-level that each plant faces, we used that to compute a weighted price using the plant-specific monthly production shares from the EMIM in 2009 as weights. For firms that entered the survey after 2009, we used the first year in which the firm appears to compute weights.[26]

$$P^e_{it} = \sum_{m=1}^{m=12} \frac{y_{im0}}{\sum_{m=1}^{m=12} y_{im0}} P^e_{imt} \tag{1}$$

where P^e_{it} 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^e_{imt} is the price that i faces in month m and year t.[27]

3.2.2 Fuels prices

To construct plant-level fuel prices, we followed four steps. First, using consumption data from SENER, we identified 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

[26] To test the robustness of these weights, we used alternatively current year weights and the results do not change.

[27] Thus, 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.

in manufacturing. Second, we obtained from the SENER fuel consumption data in each NAICS 4-digits manufacturing sector, converted fuel consumption in kWh equivalents and derived sector-specific shares.[28] Third, we combined this data with monthly national prices for diesel from SENER, for coal and coke from INEGI and monthly-regional prices for gas from SENER. Doing that allowed us to compute for each NAICS-4 digits sector monthly sector-specific composite price indices for fuels, weighted by sectoral consumption shares in 2009:

$$P^{f}_{sRm} = \alpha^{coal}_{s} P^{coal}_{m} + \alpha^{coke}_{s} P^{coke}_{m} + \alpha^{diesel}_{s} P^{diesel}_{m} + \alpha^{gas}_{s} P^{gas}_{Rm} \tag{2}$$

where α^{d}_{s} are the shares of fuel type d in total consumption of fuels in sector s and P^{d}_{m} 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).[29] For each plant f and year t,

$$ln(TFPR)_{ft} = ln(VA_{ft}) - ln(\overline{VA}) - \left[\frac{1}{2} \sum_{j=1}^{k} (S_{jft} + \overline{S}_{j})(ln(X_{jft}) - ln\overline{X}_{j}) \right]$$

In the above equation, VA_{ft} is the value added of the plant, S_{fjt} its revenue share for input j and X_{jft} real value of the same input. As it is standard, we consider capital and labor as factors of production. Upper bars represent averages within a sector and year.

[28] We use the following conversion factors: 1 litre 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.

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

Using a productivity index has two important 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. 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 Ackerberg et al. (2015) would allow some heterogeneity across sectors, but they would still assume a fixed technology over time.

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 such a reason, we also estimate TFPQ at the product-level using a trans-log production function, as in De Loecker et al. (2016). Using this methodology allows to purge the productivity measures from two important sources of bias: input price-bias and input allocation-bias. Input price bias might arise because, due to differences in quality or market power, plants might face different prices for the same input. 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. Failing to account for these sources of bias can result in biased estimates of marginal costs and thus, estimated total factor productivity.[30]

We complement the analysis using alternative measures of plants' performance. These are: i) labor productivity, defined as the log of real value added per worker; ii) profitability, defined as value added minus payments to labor over total revenue (and so results are expressed in percentage points), and iii) 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.

[30]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.

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 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.[31] 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 plant's performance and affect 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:

$$P^i_{ft} = \alpha_0 + \alpha_1 inst^i_{ft} + D_{st} + region_{rt} + u_f + \eta_{ft} \tag{3}$$

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

[31] Regions 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

In (3), $inst^i_{pt}$ 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), $i = \{fuel, elec\}$. 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 emphasize 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, $\hat{P}^i_{ft}$ is an index, obtained weighting sector-month-specific prices (sector-month-region-specific prices for natural gas and electricity) by plant-specific monthly production in a given year.[32]

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,

$$P^i_{fpt} = \sum_{f' \in p, f' \neq f}^{N_{pt}} \frac{P^i_{f't}}{(N_{pt} - 1)}$$

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

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

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,

$$\mu^i_{fpt} = \frac{P^i_{fpt}}{\bar{P^i}_t}$$

where $\bar{P^i}_t$ is the country-average price of energy source i. From the discussion on energy prices above, the markup μ^i_{fpt} 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 institutional factors that should not be subject to the plant-specific endogeneity described above. In particular strict government controls on the energy sector and prices being set at the sector, state and size-level for the case of electricity, results in largely exogenous price variation with respect to plant-level outcomes. 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 to the extent that unobservable state-sector shocks variation may affect the energy price coefficients, we also instrument plant-level price indexes for Mexico. To that end we use the average price index in the same sector, tariff, and state-average, excluding the plant analyzed. This instrument is then weighted by the plant-specific distribution of production across months in the first year.[33]

[33] We also tested alternative instruments analyzing the average index within tariff and state but excluding own sector, and average index within tariff and sector but excluding own state. Each of these composite instruments is weighted by constant initial production in the first year, and alternatively, current production. The results - available from the authors upon request -

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. For Mexico, the IV for electricity price has a negative impact on fuel prices.

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 TFPR by 1.2 percent in Mexico and 3.3 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 profitability. A 10 percent increase in fuel prices increases profitability by 0.4 percentage points in Mexico and almost 1 percentage points 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 broadly in line with the existing evidence, which finds a negative impact of electricity prices on firms' performance (Abeberese, 2017; Marin and Vona, 2017).[34] For Mexico, we find that a ten percent increase in electricity prices lowers TFPR (-2.8 percent), labor productivity (-2.4 percent), and profitability (-0.25 percentage points); unlike for the other performance measures, an increase of electricity prices increases energy efficiency. In the Indonesian sample, the effect of electricity prices on TFPR is not significant, but it has the expected negative sign.[35] The coefficients

are robust to these different specifications.

[34]Related 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.

[35]We experimented with alternative methods of estimating TFPR. The positive impact of fuel prices on performance is remarkably robust across methods and samples. For the Indonesian sample some methods result in a negative and significant coefficient for electricity prices. Nevertheless, for the reasons discussed in Section 3.3, we prefer to use TFPR index as the main

on the other performance variables are close to zero and not significant, exception made for energy efficiency that is positive, as in the case of Mexico. We return below to the possible interpretation of the more muted effect of electricity prices on performance among Indonesian plants.

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 for Indonesia and close to zero for Mexico. 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 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. On the other hand OLS estimates are very similar to the 2SLS coefficients for Mexico. That is expected, because as discusses in Section 4.1 energy prices are computed on the basis of institutional factors and so less subject to plant-specific sources of endogeneity.

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 similar results hold when we restrict the Indonesia data on the period 2009-2015.[36].

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

productivity indicator.

[36]This 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

to be embodied in electric capital vintages. A technology that is especially relevant in our framework is the heating system, used pervasively in manufacturing to shape components or transform materials. For instance, old generations of boilers are powered by coal or gasoline, while new generations of the same technology are electric (Malek, 2005). 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 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). 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 one. 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.[37] At the same time, electricity prices tend to have a negative

[37]Given 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

impact on turnover, which could plausibly capture a negative income effect.[38] 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 rely heavily on fossil combustible. These results reassure us that the effects of energy prices on machinery turnover shown in Table 3 are not an artifact of the data.[39]

In order to shed light on the type of machinery plants switch to columns 3 and 4 of Table 3 look at the impact on the electricity content of capital in both countries. Consistently with the hypothesis that fuel price hikes induce substitution towards electric machinery, we find that an increase in fuel prices results in an increase in the electricity content of capital. On the other hand an increase in electricity prices lowers, rather than increases the fuel intensity of capital in Mexico and it is not significant for Indonesia (columns 5 and 6). 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).

Further support to the hypothesis that more productive technology is embodied in electric vintages of capital is provided by Table A5 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 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

experiment using the transformation $\ln(1+x)$, which delivers similar results.

[38]For 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.

[39]Electricity prices tend to have a negative impact on turnover of other categories of assets in Mexico, which is consistent with a negative income effect.

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.[40]

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.[41]

While the main results are similar in both countries, the positive effect of fuel price hikes on performance is 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 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 USD 360 billion, Mexico's

[40]One 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.

[41]We 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.

manufacturing exports in 2018 were 4.5 times larger than Indonesia's, in spite of 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 impose a burden on the competitiveness of domestic industries. This reinforces the arguments in favor of fuel subsidy reform and carbon taxes, particularly in developing countries.

Much as in the case of other technology, such as management practices (Bloom et al., 2013), the findings also hint at some (information or otherwise) frictions that prevent firms from adopting more efficient electricity powered technology in spite of 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 broadly 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.[42] Second, the opportunity cost of the subsidy is high in countries with large needs of productive public investments, including on 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.

[42]In 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.

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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***	0.979***	-0.3141***	0.010
	(0.0015)	(0.010)	(0.0803)	(0.007)
IV price fuels	-0.0002	0.035*	0.2898***	1.023***
	(0.0002)	(0.020)	(0.0204)	(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.
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) ln(TFPR)	(2)	(3) ln(VA/L)	(4)	(5) Profitability	(6)	(7) ln(VA/KWh)	(8)
	MEX	IDN	MEX	IDN	MEX	IDN	MEX	IDN
ln(Price fuels)	0.124***	0.326***	0.244***	0.179***	0.0363***	0.093***	0.222***	0.670***
	(0.0145)	(0.048)	(0.0330)	(0.042)	(0.00611)	(0.011)	(0.0359)	(0.066)
ln(Price electricity)	-0.285***	-0.024	-0.245***	0.013	-0.0253**	-0.001	1.167***	0.332***
	(0.0324)	(0.027)	(0.0562)	(0.025)	(0.0118)	(0.005)	(0.0814)	(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	183,938	40,826	238,549	42,136	236,042	39,992	236,699
Number of plants	6,449	24,752	7,467	27,191	7,551	27,163	7,321	27,175
First stage F	129.6	997.8	136.6	1658	141.8	1657	156.2	1623

* 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 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*	0.290**	0.226**	0.211**	-0.190*	-0.458***	0.358*	0.093**
	(0.212)	(0.130)	(0.0981)	(0.090)	(-1.74)	(0.096)	(0.192)	(0.039)
ln(Price electricity)	-2.192***	-0.186***	-2.322***	-0.973***	-0.186***	0.018	0.0590	-0.015
	(0.283)	(0.071)	(0.137)	(0.061)	(-5.93)	(0.043)	(0.0639)	(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*	0.423***	0.795***	0.322**	0.876*	0.394***
	(0.217)	(0.148)	(0.306)	(0.133)	(0.50)	(0.136)
frontier*ln(Price fuels)	-0.108	-0.350*	-0.620***	-1.375*	-0,588	-0.565**
	(0.140)	(0.186)	(0.205)	(0.785)	(0.384)	(0.255)
ln(Price electricity)	-2.295***	-0.199**	-2.017***	-0.214***	-2.010***	-0.213***
	(0.300)	(0.092)	(0.299)	(0.072)	(0.327)	(0.076)
frontier*ln(Price electricity)	0.393	0.058	-0.677	0.946	-0,477	0.154
	(0.325)	(0.121)	(0.430)	(0.664)	(0.451)	(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/sale)	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
Fuelks/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	220,019	1.387	2.746	0.00164	423.9
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	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	3.114	2.066	0.956	13.804
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)		Profitability		ln(VA/KWh)	
	MEX	IDN	MEX	IDN	MEX	IDN	MEX	IDN
ln(Price fuels)	-0.00201	0.188***	0.000358	0.215***	-0.00856*	0.022***	-0.00336	0.399***
	(0.00191)	(0.010)	(0.00361)	(0.009)	(0.00499)	(0.002)	(0.00423)	(0.008)
ln(Price electricity)	-0.286***	0.323***	-0.261***	0.380***	-0.0515	0.023***	1.142***	0.528***
	(0.0311)	(0.006)	(0.0537)	(0.006)	(0.0498)	(0.001)	(0.0790)	(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	186,043	40,826	240,113	49,917	237,618	39,992	238,273
Number of plants	6,449	26,857	7,467	28,755	7,813	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.
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) ln(TFPR)	(2) ln(VA/L)	(3) Profitability	(4) ln(VA/KWh)
ln(Price fuels)	0.527***	0.283***	0.160***	0.376***
	(0.091)	(0.079)	(0.024)	(0.123)
ln(Price electricity)	-0.034	-0.077	0.013	0.185***
	(0.056)	(0.050)	(0.011)	(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	73,381	97,509	95,431	96,689
Number of Plants	14,704	17,45	17,437	17,42
First Stage F	447.5	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 EAIM and EMIM, INEGI (Mexico), and Statistik Industri (Indonesia).

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

	(1)	(2)	(3)	(4)	(5)
	ln(purchases + sales) buildings	ln(purchases + sales) vehicles		ln(purchases + sales) land	
	IDN	MEX	IDN	MEX	IDN
ln(Price fuels)	0.152	0.261	0.316***	-0.0413	0.130
	(0.120)	(0.189)	(0.116)	(0.182)	(0.095)
ln(Price electricity)	-0.040	-1.032***	-0.088	-0.719***	0.024
	(0.066)	(0.225)	(0.068)	(0.214)	(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).

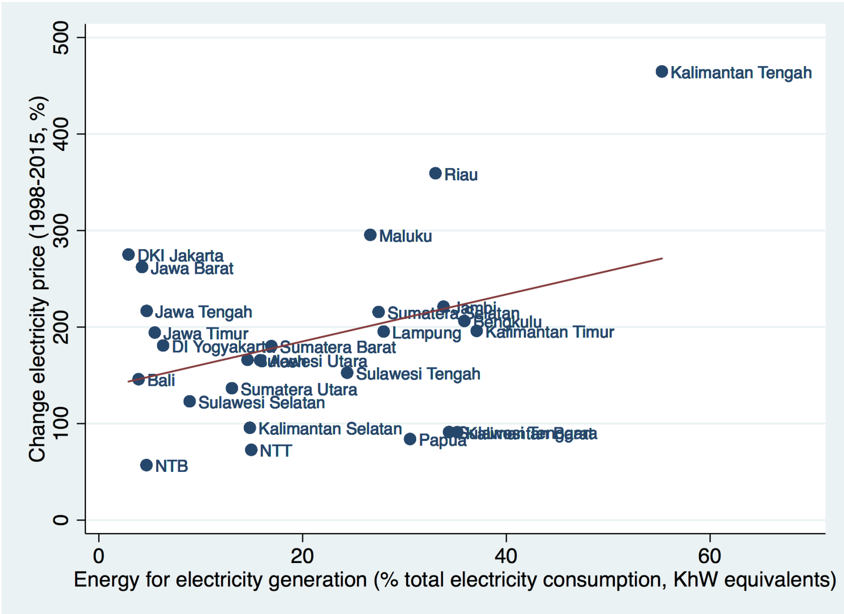
Table A5: Comparison electricity-intensive plants vs others

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ln(TFPR)		ln(VA/worker)		profitability		ln(VA/KWh)	
	MEX	IDN	MEX	IDN	MEX	IDN	MEX	IDN
Electricity gap	-0,0218	-0.002*	-0.0830*	-0.016***	-0.0236***	-0.005***	-0.253***	-0.193***
	(0.0229)	(0.001)	(0.043)	(0.001)	(0.00657)	(0.000)	(0.0502)	(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

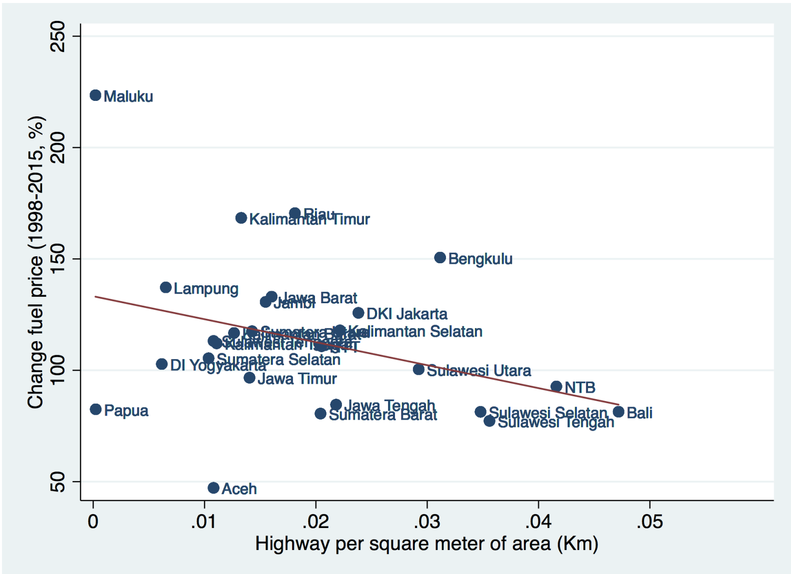
* Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level. Robust standard errors in parentheses.
Source: Authors' calculations using data from EAIM and EMIM, INEGI (Mexico), and Statistik Industri (Indonesia).

Figure A1: 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.[43] 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 is the ratio of plant-KL to the sector average KL is below 0.02 or larger than 50.[44] 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.[45] 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 mismeasured. Moreover, information on purchases and sales of capital equipment,

[43]One 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.

[44]We experiment with stricter thresholds which result in too many observations dropped.

[45]We 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 A2). Figure A3 compares original and clean capital stock series.

Figure A2: Plants' growth rate distribution of capital-labor ratio.

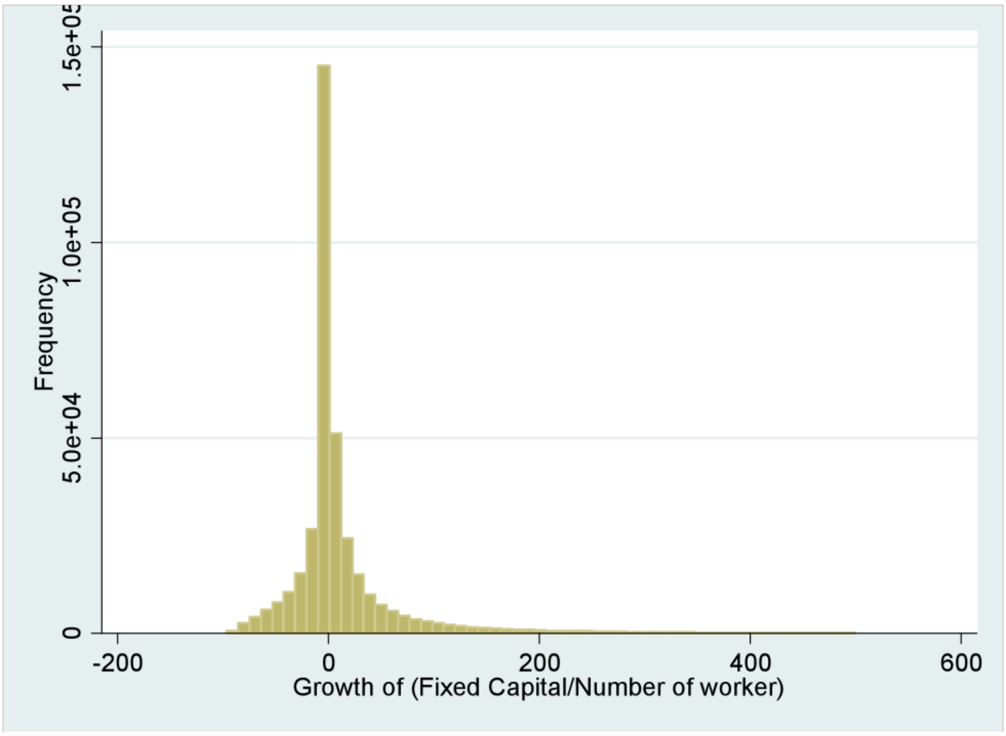
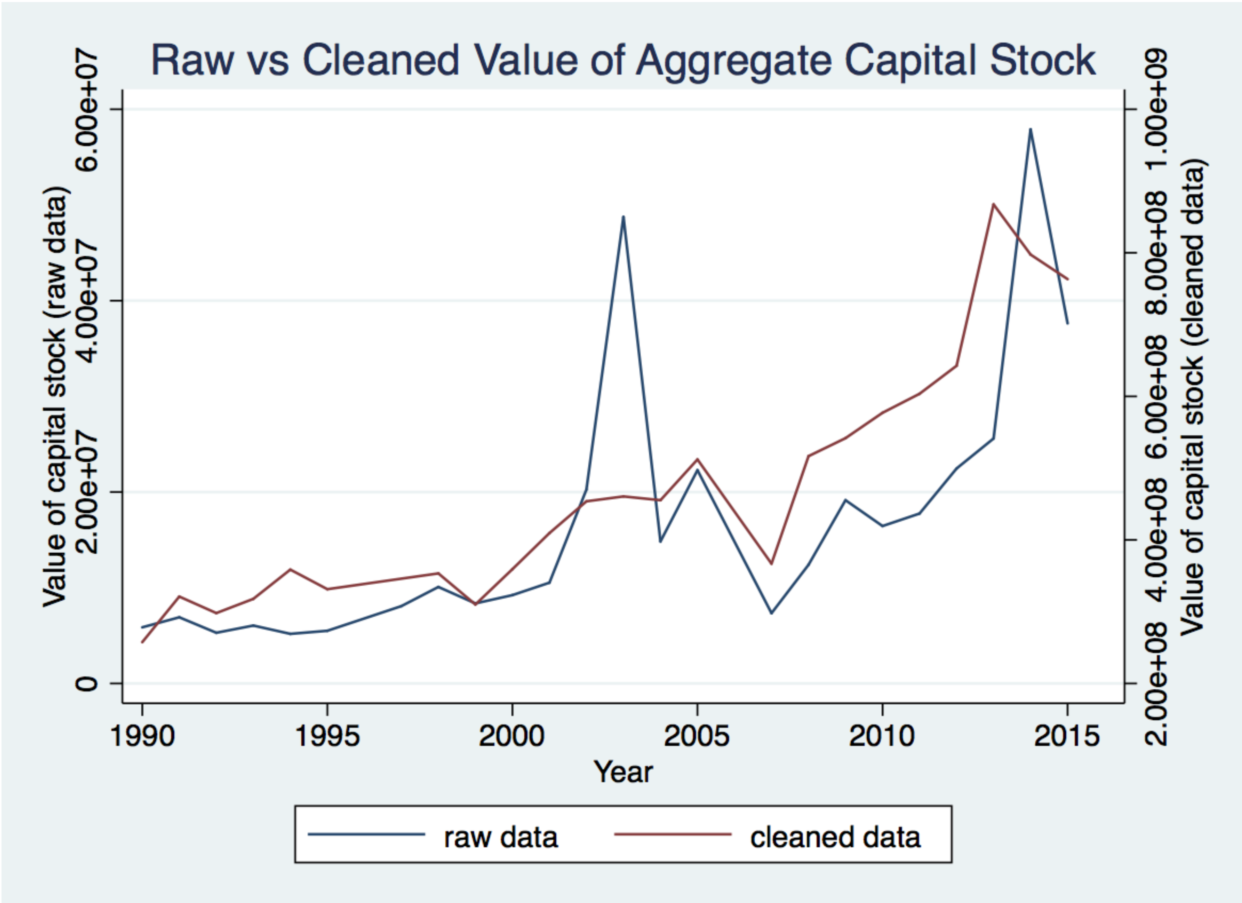


Figure A3: Comparison of Aggregate Nominal Capital Stock Series.



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