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The Impact of Energy Prices on Employment and Environmental Performance: Evidence from French Manufacturing Establishments*

Giovanni Marin† Francesco Vona‡

Abstract

This paper evaluates the historical influence of energy prices on a series of measures of environmental and economic performance for a panel of French manufacturing establishments over the period 1997-2010. The focus on energy prices is motivated by the fact that changes in environmental and energy policies have been dominated by substantial reductions in discounts for large consumers, making the evaluation of each policy in isolation exceedingly difficult. To identify price effects, we construct a shift-share instrument that captures only the exogenous variation in establishment-specific energy prices. Our results highlight a trade-off between environmental and economic goals: although a 10 percent increase in energy prices brings about a 6 percent reduction in energy consumption and to a 11 percent reduction in CO2 emissions, such an increase also has a modestly negative impact on employment (-2.6 percent) and very small impact on wages and productivity. The negative employment effects are mostly concentrated in energy-intensive and trade-exposed sectors. Simulating the effect of a carbon tax, we show that job losses for the most exposed sectors can be quite large. However, these effects are upper bounds and we show that they are significantly mitigated in multi-establishment firms by labor reallocation across establishments.

Keywords: energy prices, establishment performance, environmental and energy policy

JEL: Q52, Q48, H23, D22

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1 Introduction

The impact of environmental policies on firm performance has been a long-standing and controversial topic in the political debate, especially so because urgent responses to climate change should be given in times of tightening government budgets and increasing competitive pressure from emerging countries (EEA, 2014). While stringent environmental policies produce valuable benefits for society as a whole in terms of reduced environmental externalities, their impact on industrial production, employment and productivity is often cited as the main barrier to an ambitious implementation of such policies. It is therefore much needed to provide robust empirical evidence on the joint impacts of such policies on firm's environmental and economic performance. New evidence is particularly important to enhancing our limited understanding of the macroeconomic and firm-level responses triggered by climate change mitigation policies (e.g. carbon pricing) that are predicted to increase the cost of energy (Aldy and Pizer, 2015).

This paper pursues this goal by investigating the responses of French manufacturing establishments to changing energy prices over a variety of socio-economic and environmental variables. The historical experience of French establishments between 1997 and 2010 represents a unique opportunity to forecast the expected impact of ambitious carbon pricing policies put in place by the French government with the Energy Transition Law of 2015 (and planned by all countries that ratified the Paris Agreement on climate change mitigation). Our analysis is based on three rich datasets provided by the French Statistical Office (INSEE): the survey EACEI (Enquête sur les consommations d'énergie dans l'industrie) on energy purchase and consumption (by energy source) of French manufacturing establishments, DADS (Déclaration Annuelle des données Sociales) on employment and wage data of French establishments and FARES-FICUS on firms' balance sheets (see Appendix A). For the identification of the energy price effects, we construct a shift-share instrument that captures only the exogenous variation of establishment-specific energy prices. We motivate the choice of energy prices showing that, although significant policy changes occurred in France during the last decade, these changes have been dominated by a substantial reduction in quantity discounts for large industrial consumers of electricity and gas, making the evaluation of each policy in isolation exceedingly difficult.

Our results reveal a trade-off between environmental and economic goals due to changing energy prices. We estimate that a 10-percent increase in establishment-level energy prices brings about a 6.4 percent reduction in energy consumption and a 11.5 percent reduction in CO2 emissions. At the same time, the same 10-percent increase in energy prices also has a small negative impact on employment (-2.6 percent) and to a lesser extent on wages (-0.4 percent, but this effect is unstable across sub-samples) and firm's productivity (1.1 percent, but at a statistical level that is only barely significant). The negative employment effects differ across sectors in terms of their energy intensity and exposure to international trade, with the effect being larger in magnitude for energy-intensive and trade-exposed sectors. Simulating the effect of the planned French carbon tax, we show that job losses in the more exposed sectors can be quite large.

The academic literature has contributed extensively to the identification and quantification of possible trade-offs between environmental and economic goals. According to the neoclassical view of the firm, environmental regulation introduces an additional constraint on the firm's maximization problem, thus resulting in reduced efficiency, lower production and employment (Palmer et al., 1995; Jaffe and Palmer, 1997). On the other hand, by altering the relative prices of polluting inputs with respect to other inputs, higher energy prices will induce innovation directed at reducing the demand for more polluting energy sources, a trend documented at the aggregated level for the US by (Hassler et al., 2015). However, even in a directed technical change framework (Acemoglu et al., 2012), sustained emission reductions and long-run growth are compatible only under certain specific conditions on the elasticity of substitution between dirty and clean inputs. Theoretically, well-designed environmental regulation can lead to benefits exceeding compliance costs and thus to a positive impact on firm competitiveness only in the presence of bounded rational firms, as postulated by the Porter Hypothesis (Porter and van der Linde, 1995). Indeed, new regulations reveal opportunities for innovation, organizational improvements and changes in the input mix that were not yet considered by managers.

Although we also use productivity and wages to measures the establishment's economic performance, employment is the most important policy objective that may collide with environmental goals, and thus, employment is our primary measure of economic performance. Three main mechanisms govern the relationship between labor demand and energy prices as proxies of environmental regulation (Berman and Bui, 2001; Morgenstern et al., 2002). First, higher energy prices should negatively affect overall production and thus labor demand. Second, more expensive energy will be substituted with other inputs, such as labor or capital. Third, induced innovations contribute to both mitigate the decrease in output and enhance the substitutability among inputs. As a result, determining the sign and magnitude of the cross-elasticity between energy prices and labor demand remains an unresolved empirical question.

Note also that the aggregate effects of changes in energy price on labor demand depends also on general equilibrium effects and compositional change both within and between sectors (Morgenstern et al., 2002). At the industry level, for instance, a compositional effect may result in a faster output growth in firms with a lower share of polluting inputs as these firms will become relatively more competitive.[1] Given the difficulties in using the EACEI survey, which contains information for approximately 10000 establishments per year, to construct measures of energy price at a more aggregate level, we cannot account for these general equilibrium effects in our main empirical analysis. However, we provide an initial illustration of compositional effects, documenting a significant within-firm and across-establishments energy and labor relocations, which likely mitigate the estimated negative effect of energy price (and environmental policies) on labor and energy demand.

Our paper is related to the growing literature on the evaluation of environmental policies. Deschênes (2011) estimates a negative cross-elasticity (approx.

[1]At the macro level, structural change and international trade are likely to induce a shift in production and consumption from pollution-intensive sectors to less-polluting sectors. However, the literature documents that these effects are usually less important than within-sector technical effects (Levinson, 2015; Shapiro and Walker, 2015), with the distinct exception of the paper of (Cherniwchan et al., 2017) which accounts also for the firm-level emissions embedded in intermediate imports.

-0.16) of employment to electricity prices using within-state variation in such prices for the US. Using sector-level German data, Cox et al. (2014) also estimate a negative cross-elasticity of labor to energy prices, but the elasticity changes sign when conditioning on output. Aldy and Pizer (2015) find similar negative but relatively modest effects of energy prices on production and net import for a panel of US manufacturing sectors. Although these studies do not tackle the issue of endogeneity of energy prices, their findings are qualitatively similar to those of related studies exploiting exogenous geographical variation in command-and-control regulation, e.g. the US Clean Air Act (Greenstone, 2002; Walker, 2011; Curtis, 2017). Kahn and Mansur (2013) study the determinants of industry location for US counties sharing the same border over a period characterized by a sharp decline in US manufacturing employment, 1998-2009. They find that pollution-intensive and energy-intensive industries are highly sensitive to nonattainment designation and electricity prices, respectively.

Fewer papers use firm-level data to evaluate the effect of environmental policies. For the US, two recent papers use plant-level data to estimate the effect of changes in environmental regulation on worker's earnings (Walker, 2013) and productivity (Greenstone et al., 2012), corroborating the general result that these regulations have negative economic impacts. For European countries, Martin et al. (2014) evaluate the impact of the Climate Change Levy (CCL) on a panel of UK manufacturing plants. Partially in contrast with previous studies, their results suggest a positive but insignificant impact of being subject to the CCL on employment, including when accounting for the endogeneity of the tax, but a negative effect on energy intensity is found. Flues and Lutz (2015) and Gerster (2017) both evaluate the impact of a discontinuous change in electricity taxation on the performance of German manufacturing establishments by means of a regression discontinuity design and a fuzzy regression discontinuity design, respectively. In both cases, establishments around the discontinuity did not experience any different performance in terms of gross output, export, employment, value added or investments (see also, von Graevenitz et al., 2017).

Other recent contributions look at the impact of the EU-ETS on firms' competitiveness, with mixed results. Wagner et al. (2014) evaluate the impact of the EU-ETS on the performance of French manufacturing plants, finding the impact to be negative and significant on employment, while no significant effect was found on employment by Petrick and Wagner (2014) and Anger and Oberndorfer (2008) for German firms. Abrell et al. (2011), on the other hand, evaluated the impact of the EU-ETS on a panel of European firms in different countries, finding no effect on profits and value added and a negative small and significant effect on employment.

We contribute to the literature in four ways. First, in contrast to the papers reviewed above, which exploit the variation in firm-level environmental policy driven by specific and sometimes small regulatory changes affecting a small (and often non-randomly selected) fraction of firms, our paper employs a more pervasive indicator of potential exposure to environmental policies, i.e. energy prices.[2] Second and crucial to validating our choice of energy prices, we correlate

[2] This choice follows leading contributions in the literature (see, among others, Newell et al., 1999; Popp, 2002; Aldy and Pizer, 2015; Ley et al., 2016). What makes the use of energy prices attractive is the fact that most environmental policies directed at reducing air pollution or contributing to climate change mitigation, especially those relying on market-based instruments, result or will result in increasing (directly or indirectly) the cost of burning

the evolution of energy prices in the French manufacturing sector with both policy- and nonpolicy-related drivers. We show that as in the related paper of Davis et al. (2013) the latter (notably changes in quantity-discounts) dominates over the former, and thus acts as an effective increase in policy stringency for energy-intensive firms. Third, we address the important issue of endogeneity in the estimates of the causal effect of energy prices on establishments' economic and environmental performance. In doing so, we propose a flexible shift-share instrument that is easily amenable to be used in other contexts and can be used to simulate the effect of climate policies. Finally, our rich database allows us to start investigating the within-firm reallocation effects, thus contributing both to the debate on the role of the internal labor market as insurance against negative shocks (Cestone et al., 2016).

[Figure 1 about here]

A further contribution of our paper is to consider the case of France, which is particularly interesting for two reasons. First, France features low prices for energy, especially electricity, relative to its neighboring countries. As reported in Figure 1, the electricity price for industrial consumers belonging to different bands of yearly consumption (year 2010, Eurostat data) was much lower in France than in Italy and Germany, approximately 30-40 and 40-50 percent cheaper, respectively, across different consumption bands. These systematically lower energy prices may have made the French manufacturing sector less prepared and thus more vulnerable to changes in energy prices than the manufacturing sectors of other countries. Second, the electricity and natural gas markets experienced substantial changes due to the combination of increasing market liberalization, setting of ambitious environmental targets and the introduction of a tax on electricity (IEA, 2004, 2009). Interestingly, these policy changes have been associated with substantial changes in the structure of energy prices paid by different industrial costumers. This differentiated impact across different industrial consumers is a particularly helpful source of variation to be exploited to identify the impact of energy prices on the performance of French manufacturing establishments.

The paper is organized as follows. Section 2 first describes a series of stylized facts about energy consumption and the costs of French manufacturing, and then, we show how changes in the regulatory framework have affected the structure of energy prices paid by industrial costumers. Section 3 illustrates the empirical strategy to estimate the effect of energy prices, while Section 4 discusses the main results and several extensions. Section 5 concludes.

2 The changing structure of energy prices in the French manufacturing sector

As an essential first step toward the evaluation of the impact of energy prices on establishments' performance, this section analyses the extent to which energy prices differ across establishments and identifies the drivers of this heterogeneity. In doing so, we evaluate the association between policy changes and energy prices at the establishment level.

fossil fuels.

2.1 Data, measures and basic facts

The main source of information about the energy use and expenditures of French manufacturing establishments for the period 1997-2010 is the EACEI survey. EACEI collects detailed information on energy consumption and expenditure by energy source (13 sources) for a representative sample of manufacturing establishments with at least 10 employees. Further details about the EACEI survey are discussed in Appendix A.

Similar to Davis et al. (2013), what we label as energy price is just the average unit cost of energy, which is the ratio between total energy expenditure and total energy consumption. This measure does not say anything about the actual price schedule for different energy sources within each establishment or the marginal price of energy. This limitation, however, is somewhat compensated by the advantage of having access to establishment-specific information for both energy prices and key economic variables. In the following, we will use the word 'price' to refer to the unit value cost of energy, that is:

$$p_{it}^{E} = \sum_{j=1}^{13} \phi_{it}^{j} p_{it}^{j}, \tag{1}$$

where ϕ_{jit}^{j} is the share of energy consumption of source j (i.e. natural gas, electricity, etc.) on total energy consumption, while p_{it}^{j} is the average unit value cost of energy source j paid by establishment i at time t.[3]

As is clear from equation 1, cross-establishment heterogeneity in energy prices primarily depends on the heterogeneity in the energy mix. Indeed, for a given vector of prices for all possible energy sources, establishments with different energy mixes will pay a different average price per kWh equivalent of energy. Figure 2 reports the energy mix of the 'average' French manufacturing establishment, and these values appear quite stable throughout the period 1997-2010. The average French manufacturing establishment relies substantially on the consumption of electricity (mostly from nuclear, e.g. 77 percent in 2013), which accounts for approximately 60 percent of total energy consumption and has modestly increased by approximately 3 percent over the period considered. The second most important energy input is natural gas, which accounts for approximately 20-30 percent of total energy consumption and has also gained importance with an increase of approximately 5 percent over the period considered. Conversely, the share of heating oil decreased substantially from approximately 12 percent in 1997 to approximately 5 percent in 2000. Finally, other fuels (heavy oil, oil, steam, coke, other gas, coke-petrol, and lignite) only represent a very small share of the energy input for the typical establishment.

[Figures 2 and 3 about here]

Changes in the (establishment-specific) prices for different sources represent the other main source of variation in the average energy price. Figure 3 summarizes the trends of nominal average unit cost of energy (euro per kWh) for different energy sources: total energy , electricity, gas and other sources.[4] First,

[3]Energy consumption for all energy sources has been converted into kWh-equivalent values.

[4]'Gas' includes natural gas, butane-propane and other gas; 'Other' includes heating oil, heavy oil, oil, steam, coke, coke-petrol and lignite.

notice that, on average, all energy prices increased substantially over the time period considered. Second, the timing of the price increases is similar for both gas and electricity. The price of electricity was declining until 2003, after which a sharp increase is observed, while the prices of natural gas and other sources started to increase in 2004 reflecting the global upward trend in fossil-fuel prices. Third, electricity is the most expensive energy source, but the gap in the price per kWh between electricity and other energy sources shrank between 1997 and 2010. To illustrate, one kWh of electricity was approximately 3.4 times more expensive than a kWh of gas in 1997 and approximately 1.9 times more expensive in 2010.

[Table 1 about here]

Even though aggregate energy prices and, even more so, the energy mix appear to be rather stable over time, what matters to our analysis is the degree of across establishments heterogeneity in energy intensities, prices and mixes. Energy intensity, i.e. the incidence of energy-related costs measured[5], is a good proxy of the degree of exposure (of an establishment or of a sector) to policy-driven changes in energy prices, while the energy mix is a good proxy of the establishment's technology.

Table 1 reports the averages and standard deviations (in parentheses) of these energy-related measures broken down by sector (2-digit NACE rev 2). The bottom line is that energy intensities, prices and mixes all display substantial variation both between and within sectors.

In more detail, the first column shows that, on average, for each euro paid in wages, the typical French manufacturing establishment pays 0.217 euro for purchasing energy. The very large coefficient of variation in energy intensity (2.2) is driven by both between- and within-sector heterogeneity. To illustrate, the ratio between energy expenditure and wages is 0.081 for Wearing apparel and 0.381 for Basic metals, while the within-sector coefficient of variation is always much greater than one. The heterogeneity in average energy prices (second column), electricity prices (third column) and gas prices (fourth column) prices is smaller than the heterogeneity in the incidence of energy costs: the aggregate coefficients of variation are 0.33, 0.26 and 0.33, respectively. However, again both cross-sector and within-sector heterogeneity matter. Finally, the fifth and the sixth columns of Table 1 reveal that the documented stability in the aggregate energy mix masks a substantial heterogeneity both within and across establishments. This finding is particularly important for our estimation strategy: changes in the relative prices of different energy sources have heterogeneous impacts on the average unit cost of energy of establishments with *different* energy mixes and *similar* energy intensities.

2.2 Heterogeneity of energy prices across manufacturing establishments

To evaluate in greater detail the drivers of price heterogeneity across establishments, we closely follow the the approach used by Davis et al. (2013), who

[5]This is measured as the ratio between energy expenditures and the wage bill. We use total wages paid as the denominator as this is the only monetary variable that is systematically collected for all establishments in our sample.

analyze electricity prices across US manufacturing establishments for the US over the period 1963-2000. The authors document a remarkable dispersion in energy prices across US establishments and show that the decline in such dispersion is mostly associated with a reduction in quantity discounts for large industrial consumers. Here, we extend their analysis considering both total average energy prices and electricity alone given that the French electricity market has been affected by substantial regulatory changes over the time period of our analysis.

[Figure 4 about here]

Our measure of prices dispersion is the purchase-weighted standard deviation across establishments of the logarithm of energy prices for each year in our sample. In Figure 4, the standard deviation of total energy prices declines from approximatively 55 log points in the first years of the series to about 30 log points in the last years. As for the average electricity prices, we observe no clear trend up to 2003 and a downward trend starting in 2004. Moreover, the dispersion in electricity prices is systematically smaller than that of total energy prices.[6] This reflects the fact that total energy prices also incorporate heterogeneity in the energy mix across establishments. Overall, what we observe for total and electricity energy prices is both a great degree of cross-establishment heterogeneity and a substantial reduction in this heterogeneity, especially over the last six years of our series.

[Figure 5 about here]

As next step, we decompose the overall standard deviation of energy prices into three main structural components: i) quantity discount or size of energy consumption (by using year-specific deciles of energy consumption), ii) sectors (2-digit NACE rev 2), iii) regions (NUTS2).[7] Te results for total energy prices (top panel) and electricity prices (bottom panel) are reported in Figure 5. At the beginning of the sample period, both the sectoral and the size component explain alone approximately 70 percent of the dispersion in energy prices (total and electricity), while geographical variation accounts for only 38 percent of total price dispersion. Notably, although we also observe a decline in the importance of the sectoral component, the overall decline in price dispersion has been primarily driven by a sharp decline (from 70 to less than 50 percent) in the importance of the size component, which mostly occurred after 2004. Compared with results for the US (Davis et al., 2013), quantity discounts play not only a more important role in explaining price heterogeneity, but also display a more marked decline.

[6] Note also that the dispersion in electricity price is around 10 log points below the values estimated by Davis et al. (2013) for the US in the same period. This finding can be explained by the significantly lower geographical dispersion of French electricity prices compared to that of the US prices.

[7] Practically, we first take the yearly average of total energy price and electricity prices (weighted for sampling weights multiplied by total energy consumption and electricity consumption of the establishment, respectively) within each category of the component (e.g., within each sector). We then compute for each year the standard deviation of log energy and electricity prices across categories of the selected dimension. Finally, we take the ratio between the dimension-specific standard deviation and the total (across-establishments) standard deviation. This ratio describes the share of price heterogeneity explained by each component. As we evaluate all components separately, the components do not sum up to one.

[Figure 6 about here]

Using a simple variance decomposition, the evolution of the role of quantity discount is not isolated from that of the sector and region components. To reinforce the basic facts presented above, we evaluate the evolution over time of the elasticity of energy price to the quantity of energy consumed conditional on a set of intervening factors. In doing so, we estimate this cross-sectional elasticity conditional on sector dummy variables (2-digit NACE) and region dummy variables. The absolute values of the estimated elasticities (which are all negative) are reported in Figure 6. The average estimated elasticity for total energy prices declines by almost 1/3 from 0.16 to 0.11. This is a remarkable difference as the range of variation in energy consumption is large and would hence imply robust quantity discounts. For instance, the price discount for one interquartile range in total energy consumption was of approximately 36.5 percent in 1997 and only 23.1 percent in 2010. The elasticity of electricity prices to the quantity of electricity that is consumed is slightly smaller, but follows exactly the same trend declining from 13 to approximately 8-9 percent. The difference in the level of the elasticity between total energy and electricity reflects the fact that large companies are likely to use a more differentiated energy mix and thus accumulate discounts on several energy inputs. It is worth emphasizing that as for the other series, the acceleration in the decrease of quantity discounts occurred from 2004 onward. As shown in Appendix C, the reduction in quantity discounts occurred also within establishments controlling for establishment-level fixed effects and other covariates.

The next section tries to connect the evidence on quantity discount reductions with the policy and regulatory changes that occurred in the time span considered by our study.

2.3 Regulatory and policy changes in the energy sector

The energy sector was characterized in the years 1990s and 2000s by very important regulatory changes. As in other countries, these changes were aimed at improving the functioning of market mechanisms within the concentrated and vertically integrated French energy sector and at reducing the environmental impact of energy consumption in the industrial sector.

[Figure 7 about here]

Deregulation of Energy Markets. To provide a grasp of the extent of changes in the regulatory burden in the electricity and gas markets, Figure 7 displays the OECD index of Product Market Regulation of the two sectors for France over the period 1997-2010. The index measures the importance of various dimensions of regulations in a comparable way across OECD countries. The electricity sector was 'fully regulated' (PMR=6) in France up to 1998, after which various reforms contributed to liberalizing the French electricity market. According to the IEA (IEA, 2004, 2009), the three most important reforms in this respect were: the creation of an independent transmission system operator, the non-discriminatory third-party access to the network and the transformation of EDF from an EPIC (établissement public industriel et commercial) into a limited company (société anonyme) in 2004. A similar process of reforms also substantially changed the French market for natural gas with the transformation of GDF into a limited company and the unbundling and opening to third party access to underground storage of natural gas. These reforms, despite the continuing dominant position exerted by the (mostly) publicly-owned EDF and GDF, allowed the entry of new players in the market and induced changes in the market structure and in the tariffs offered to customers.

Tax to support renewable energy. Another very important change in the regulation of the electricity market was represented by the introduction in 2002 of an electricity tax to finance renewable energy generation, "Contribution au Service Public de l'Electricité" (CSPE henceforth). The tax is levied on all final consumers of electricity and is aimed at refunding to EDF the costs due to the provision of public services. More specifically, the revenue is primarily (but not exclusively) used for covering the obligatory purchase by EDF of electricity from renewable energy and co-generation.[8] The tax per MWh increased rapidly over the last decade growing to 3 euro in 2002, 3.3 euro in 2003, increasing to 4.5 euro in 2004, 9 euro in 2011, 10.5 euro in 2012, 13.5 euro in 2013, 16.5 euro in 2014 and 19.5 euro in 2015.[9] Big industrial consumers of electricity are partly exempted from the contribution. A first limit at the establishment level is set on the total annual tax: the limit was set to 500,000 euro in 2003 and grew up to 569,418 euro in 2013. An additional plafond is guaranteed at the company level: the part of tax paid that exceeds 0.5 percent of the company's total value added is reimbursed in the following year for those companies that consume more than 7 GWh per year. Finally, consumption of self-produced electricity is exempted up to 240 GWh per year. This means that the marginal tax after the limit is reached is zero while the actual average tax on each kilowatt for big industrial plants is substantially smaller than that for smaller electricity consumers.

The *ceteris paribus* impact of the tax on quantity discount should have been unequivocally positive as big purchasers of electricity receive a substantial exemption.[10] However, given that EDF remained a *de facto* monopolist in the French electricity market even after the deregulation, the monopolist (EDF) could have simply adjusted price-discounts and tariffs to fully appropriate the tax exceptions for large consumers. In Appendix D, we directly assess the impact of the tax on energy prices around the threshold using a regression discontinuity design. Surprisingly, we observe that establishments right above the limit threshold experience an increase in price with respect to establishments right below the threshold. This increase represents a first evidence that reductions in quantity-discounts appear to be more important than policy reforms in changing the structure of French energy prices.

EU Emission Trading Scheme. Finally, European policy to tackle climate change may have significantly influenced energy prices over the period consid-

[8]The other two main goals of the CSPE are as follows: i) subsidizing electricity production and distribution in regions (i.e. oversees territories) not connected to the mainland network; ii) covering the contribution for special electricity prices granted for 'products for primary needs' and poor citizens.

[9]The tax represents a relevant component of the tax-inclusive electricity prices: 6 percent in 2002, 6.9 percent in 2003, 8.6 percent (on average) for 2004-2010.

[10]To illustrate, an establishment consuming 150 GWh per year in 2013 would have paid a total tax of 2.025 million euro. However, thanks to the limit set at 569,418 euro, the actual tax rate per MWh for this establishment was 3.79 euro per MWh instead of 13.5 euro per MWh paid by establishments below the limit threshold. The average discount on per-MWh consumed is thus approximately 72 percent.

ered by our analysis. The main climate policy at the European level is the EU Emission Trading Scheme (EU-ETS). The scheme was approved in 2001, its first pilot phase started in 2005 and its second phase began in 2008.[11] By imposing a price on GHG emissions for establishments that pass certain sector- and process-specific thresholds of installed capacity, the EU-ETS increases the overall price paid to burn fossil fuels and has an indirect influence on the price of electricity that is produced with fossil fuels.[12]

Estimating Policy Drivers. As a final step of this overview of the role of energy-related policies in driving energy prices, we assess the combined role of all policy-related drivers on energy prices and mixes, our key proxy of technology. We use a specification similar to that described in Equation 8:

$$Y_{it} \quad = \quad \alpha_i + Policy'_{it}\beta + X'_{it}\gamma + \epsilon_{it}, \qquad (2)$$

where Y_{it} is the outcome variable (either average energy price or the share of gas or electricity) in year t for establishment i, $Policy'_{it}$ is a vector of firm-specific measures of policy change (see below) for establishment i and year t, α_i is the establishment fixed effect, ϵ_{it} is the idiosyncratic error term and X_{it} is a vector of control variables that account for a variety of unobserved year-specific effects (i.e., region-by-year and sector-by-year dummies, see the discussion after equation 3 for details).[13]

We account for changes in product market regulation by building a establishment-specific PMR index by multiplying the PMR indexes (rescaled to a range between 0 and 1) for gas and electricity by the initial establishment-specific share of gas and electricity, respectively, in the energy mix. We also compute the year- and establishment-specific average CSPE tax rate, also accounting for the establishment-specific exemption. This variable is equal to zero up to year 2001, equal to the full tax rate in 2002-2010 for establishments below the year-specific exemption threshold and varies between the full tax rate and zero in 2002-2010 for those establishments that pass the exemption threshold. Finally, we interact the EU ETS dummy variable (which is equal to 1 for establishments covered by the scheme) with a dummy variable for the 'anticipation' period (2001-2004, between the approval of the directive and the first year of the scheme), a dummy variable for the first phase of the ETS (2005-2007) and a dummy variable for the second phase of the ETS (2006-2008).

[Table 2 about here]

[11] Different from the first phase, the second phase had i. a higher penalty for non-compliance (from 40 to 100 euro per ton of CO_2); ii. the inclusion of N_2O emissions; and iii. the possibility of banking permits across phases.

[12] Another indirect effect is linked to the fact that an increase in the overall price of certain energy sources (i.e. fossil fuels) induces firms to change their energy mix towards those energy sources that were relatively more expensive before fossil fuels were surcharged with the permit price (Martin et al., 2016).

[13] We include sector dummies (NACE rev 2, 2 digit), region dummies (NUTS2), ETS dummies (equal to 1 for establishments covered by the EU ETS), a peak-exposure dummy (equal to one for establishments that in their first year in EACEI were in the fourth quartile of the ratio between subscribed capacity for electricity consumption - MW - and actual annual electricity consumption - MWh) and size class dummies in the first year of observation (10-49 employees, 50-99 employees, 100-249 employees, 250-499 employees and 500 or more employees) to control for the establishment bargaining power unrelated to energy consumption.

The results are reported in Table 2. We focus on Column 4 where we jointly evaluate all policies. As would be expected, the reductions in the PMR are significantly related to reductions in energy prices. More specifically, a full deregulation of both the gas and electricity markets would have resulted in a reduction in the average energy prices paid by French manufacturing establishments of approximately 12 percent. In line with previous evidence, an increase in the CSPE tax rate has the counter-intuitive effect of reducing the average energy prices as these prices have been dominated by quantity discounts reductions. A 1-euro cent increase in the tax rate per MWh reduces energy prices by approximately 0.8 percent. Interestingly, ETS establishments experienced a faster increase in average energy prices than other establishments already before the ETS was in place. However, as indicated by the positive and significant coefficient of the anticipation dummy, the effect of the ETS on energy prices was already present before the ETS was in place. Again, a likely candidate for these differential trends is the widespread reduction in quantity discounts that have arguably affected bigger ETS establishments more than non-ETS ones. Finally, Columns 5 and 6 present estimates of the correlation between changes in energy prices and in the energy mixes.[14] While the EU-ETS did not have a significant impact on the establishments' energy mix, the CSPE induced the expected substitution between electricity and gas.

Summary. Our estimates of the policy drivers, although not causal, are useful to assess the conditional correlation between the introduction of new policies and energy prices. The main conclusion is that reductions in quantity discounts have been far more important than the introduction of new policies in explaining the changes in the structure of energy prices of French manufacturing establishments. A notable example is the inversion of the conditional and unconditional effect of the CSPE on energy price. Our results also suggest that it is difficult to perform separate evaluations of each single policy in presence of monopolists, such as EDF and GDF, that used their market power to differentiate the pass-through of the policy costs to different consumers. All this considered, our analysis lends further support to the use of energy as best proxy for environmental regulatory stringency.

3 Empirical strategy

This section illustrates the empirical strategy used to estimate the impact of energy price changes on establishment performance. We consider two dimensions of establishment performance. A first set of variables refers to environmental performance: total energy consumption (in kWh, from EACEI) and CO2 emissions.[15] Concerning economic variables, our primary measures are total employment and average wage per employee in DADS (Déclaration Annuelle des Données Sociales) for the population of French establishments. We link this information to EACEI establishments by means of a unique identifier (SIRET). As our panel of establishments is unbalanced, our primary estimation comprises

[14]We do not include PMR in these regressions as the establishment-level measure of PMR is calculated using the electricity and gas share of total energy.

[15]We computed CO2 emissions by multiplying each energy source by its technical CO2 emission factor. Since electricity and steam do not generate any direct emissions, observations for which all energy consisted of electricity and/or steam were automatically excluded from the estimation sample for this variable.

establishments that are included in the EACEI survey at least twice.[16] Finally, establishments are not required to compile and submit the balance sheet or the income statement; thus, we cannot estimate the effect of energy prices on productivity at the establishment level. In an extension, however, we estimate the impact of energy prices on different measures of productivity at the firm level for a selection of establishments that are fully observed in ECAI.

3.1 Baseline estimation framework

Our starting point is the following equation:

$$\log(y_{it}) = \alpha_i + \beta \log(p_{it}^E) + X_{it}'\gamma + \epsilon_{it}, \tag{3}$$

where y_{it} is the outcome variable (e.g. employment, energy) of establishment i in year t, α_i is the establishment fixed effect, p_{it}^E is the average cost of energy (euro per kilowatt) of establishment i in year t, X_{it} is a vector of control variables and ϵ_{it} is the idiosyncratic error term. The vector X_{it} includes includes 2-digit sector dummy variables, region dummy variables, ETS dummy variables, peak-exposure dummy variables and size class dummy variables all interacted with year dummy variables (see footnote 13 for a detailed definition of these variables). Region- and sector-specific year dummies account for any kind of unobservable demand or supply shock that hits all establishments in a region or sector and could affect both energy prices and the outcome variables. ETS specific year dummies account for the fact that we found systematically different trends in energy prices between ETS and non-ETS establishments even before the ETS was operative (see Table 2). Because an evaluation of the ETS goes beyond the scope of this paper, we account for the ETS in a flexible manner.[17] Accounting for the exposure to peak-hour electricity prices is also important as this variable incorporates useful information about the type of technology used by the firm, which is correlated with both energy prices and performance. Finally, initial size class dummies interacted with year dummies are included to capture the fact that smaller firms grow faster than bigger ones conditional on survival (see e.g. Bottazzi et al., 2011) . As size is also correlated with energy prices, this dynamics allows firms of different sizes to have different employment dynamics.

If the assumption of absence of correlation between ϵ_{it} and $\log(p_{it}^E)$ is satisfied, $\hat{\beta}$ represents the unbiased estimate of the elasticity of the outcome variable with respect to energy prices. Because a carbon tax has the effect of making fossil fuels more expensive, this parameter can be directly interpreted as the elasticity of the outcome variable with respect to the tax. It is also important to emphasize that what we estimate is the within-establishment response to a change in energy prices. Whatever happens to the relocation of production

[16] As we will discuss in section 3.2, we also exclude years 1997-1999 from the estimation sample because we use the lagged establishment-specific energy mix to build our instrumental variable. This means that in addition to the two observations per establishments that contribute to our estimates, we also need to observe the establishment one more time to build our IV. In Appendix B, we illustrate that there are systematic differences between establishments in the estimation sample and establishments that were excluded from the estimate. In particular, the former are larger and more energy intensive than the latter.

[17] A comprehensive policy evaluation on the impact of the ETS on the performance of French establishments is done in Wagner et al. (2014).

across establishments within the same firm or sector, or across different sectors in response to changing energy prices is not incorporated in $\hat{\beta}$. Since relocation effects are likely to mitigate the effect of price changes, our estimates are an upper bound of the true effect of such tax. Section 4.5 represents an initial attempt to tackle this issue.

3.2 Endogeneity issues

Endogeneity is a concern in our estimation framework due to the presence of omitted variables. There are three types of variables that are difficult to observe but that are likely to be correlated with both our outcome variables and energy prices. First of all, if establishments are hit by an idiosyncratic negative demand shock d_{it}, they will reduce output and, in turn, reduce the demand for inputs including energy and employment. At the same time, in presence of contracts for energy supply (especially so for electricity and gas) that were signed before d_{it} was observed, a lower demand for energy will increase in the average unitary cost of energy through a reduction in quantity-discounts.

Second, endogenous energy-saving technical change a^E_{it} is likely to simultaneously reduce the consumption of energy and quantity discounts offered to firms, thus increasing the average unitary cost of energy.[18] This implies that a^E_{it} should bias the impact of energy prices on energy-related outcomes in the same direction as d_{it}. In contrast, the correlation between a^E_{it} and socio-economic outcomes such as employment should be zero. Finally, as a response to an increase in energy prices, technical change can facilitate the substitution of energy with labor and capital (Hassler et al., 2015), or redirect technical change towards labor and capital (Acemoglu et al., 2012). A change in the elasticity of substitution ε_{it} between labor and energy will further reinforce the increase in energy prices and be positively (resp. negatively) correlated with labor (resp. energy) demand.

To guide our expectations regarding the sign for the omitted variable bias for labor L (our example for socio-economic outcome) and energy E (our example for environmental outcomes), it is useful to inspect the formula of the omitted variable bias (Angrist and Pischke, 2009):

$$\hat{\beta}_y = \frac{Cov(y_{it}, p^E_{it})}{Var(p^E_{it})} = \beta_y + \underbrace{\gamma_{y,d}\delta_{p,d}}_{\text{-}} + \underbrace{\gamma_{y,a^E}\delta_{p,a^E}}_{\text{-}} + \underbrace{\gamma_{y,\varepsilon}\delta_{p,\varepsilon}}_{\text{+ L, - E}}, \tag{4}$$

where δ_s are the coefficients of a regression of energy prices on the vector of omitted variables $[d\ a^E\ \varepsilon]$, while $\hat{\gamma}$s are the coefficients of a regression of the outcome variables on p, the standard controls and the vector $[d\ a^E\ \varepsilon]$. Note first that all the shocks are positively correlated with energy prices (that is, the δ_s are all positive) and thus the sign of the biases only depend on the correlations between the outcome and the omitted variables. The negative demand shock should reduce the size of the estimated coefficient $\hat{\beta}_y$ with respect to the true one, β_y. Indeed, $\gamma_{y,d}$ is negative for both E and L. Energy-saving technical change has no effect on L but has again a negative effect on E. The change in the possibility of substituting energy for labor is positively correlated with L and negatively correlated with E.

[18] The inducement effect of energy prices on energy-saving innovation is empirically well documented (Popp, 2002; Hassler et al., 2015).

As a result, the bias in the our FE estimates of β_y should be clearly negative for energy and thus, given the negative sign of β_y, overestimate the magnitude of the own-elasticity of energy demand to price. On the other hand, the direction of the bias is unclear for labor and depends on the relative magnitude of the negative bias associated with unobservable demand shocks and of the positive bias related to the substitution of labor for energy. However, because our estimates are conditional on survival, the second bias should dominate the first because surviving firms are likely to have better managers who can find solutions to transform the permanent increase in energy price in an opportunity for employment growth (Martin et al., 2012).

One way to deal with these multiple omitted variable biases is to identify an instrumental variable that is correlated with exogenous variation in energy prices but that is unrelated to establishment-specific demand shocks and endogenous technological responses to changes in energy prices (i.e. energy-saving and factor substitution). To fulfill this requirement, we propose a shift-share instrument (Bartik, 1991) that combines the nationwide prices of different energy sources with the time-invariant firm-specific energy mix. Specifically, we weigh the average national price of each energy source for the energy mix used by the establishment three years after its first entry in the EACEI survey. This instrument closely resembles the average energy price as computed in equation 1:

$$p_{it}^{IV} = \sum_{j=1}^{13} \sum_{k=2000}^{2010} \phi_{i,k-3}^{j} p_t^j. \tag{5}$$

Nationwide price variations are by construction uncorrelated with firm-specific demand shocks, while blocking the energy mix in the initial period shuts down the influence of endogenous technical change that mostly operates through changes in the energy mix. The 3-years lag in computing the initial energy mix is used to mitigate concerns that forward-looking rational managers forecast the evolution of source-specific energy prices in the coming years and choose the energy mix in year t accordingly. For this reason, the estimation sample runs from 2000 to 2010 rather than from 1997 to 2010.

We explicitly test the validity of the exclusion restriction for what concerns the possibility that, due to some additional unobserved factors, establishments with different initial energy mixes exhibit different pre-trends in the outcome variable. If this were the case, our shift-share instrument could not disentangle the exogenous change in energy prices from pre-existing systematic differences in trends across firms with different initial mixes. In doing so, we estimate the differences in pre-CSPE employment (which is available in DADS for all establishments and all years) for firms with different initial (1997) energy mixes up to year 2001, the year before the introduction of the CSPE.[19] We detect pre-treatment differences using the following equation:

[19] We include only those establishments that were observed for all years in DADS between 1997 and 2001. Energy consumption and CO2 emissions cannot be evaluated here as these variables are available for all years between 1997 and 2001 only for a very small number of establishments, while data on employment from DADS are available for the population of French establishments active in all years.

$$\log(L_{it}) = \alpha_i + \sum_{t=1997}^{2001} \beta_t^{j=gas} \phi_{i,t=1997}^{j=gas} + \sum_{t=1997}^{2001} \beta_t^{j=el} \phi_{i,t=1997}^{j=el} + X_{it}'\gamma + \epsilon_{it} \quad (6)$$

where $\log(L_{it})$ is the logarithm of employment in establishment i and year t, α_i is the establishment fixed effect, X_{it} is the usual set of control variables (see footnote 13) and ϵ_{it} is the idiosyncratic error term. We focus on the two main sources, gas and electricity (which account for over 80 percent of total energy consumption for the 'average' French manufacturing establishment), allowing the effect of their initial shares $\phi_{i,t=1997}^j$ to vary over time.[20] To detect the existence of different pre-treatment trends, we jointly test the null hypothesis that $\hat{\beta}_t^j$ are equal to zero.

The results are reported in Table 3. In column 1 we simply replace the vector X_{it} with year dummies, while the results in column 2 also account for X_{it}. Without accounting for X_{it}, we observe that firms that relied more heavily on electricity in their energy mixes in 1997 grew significantly faster than firms with smaller share of electricity. The F test of joint significance fails to accept the null hypothesis of common trends for electricity with p<0.01. However, when also accounting for our set of control variables X_{it}, all tests suggest that conditional on controls no difference in pre-trends is observed for firms with different initial energy mixes.

[Table 3 about here]

This result has two implications for our analysis. First, the reliance of our IV on time-invariant energy mix does not bear the risk of capturing pre-existing differences across establishments that are connected with the energy mix itself. Second, the set of control variables X_{it} matters for the validity of our IV strategy.

4 Estimation results

This section is organized in five distinct sub-sections. The first presents the main results. The second focuses on the heterogeneous responses of different sectors. The third simulates the effect of a carbon tax. The fourth presents firm-level results to gage the impact of energy prices on productivity, while the fifth examines energy and workers' relocation between establishments within the same firm.

4.1 Main results

The baseline results are reported in 4, where we present, for each outcome variable, results both for the simple fixed effect model and for the fixed effect model with energy prices instrumented as described above. Across the board, we observe that an increase in the unitary energy cost decreases the use of environmental and labor inputs. However, both the estimation bias and elasticity vary substantially for different measures.

[20] Since $\sum_{j=1}^{13} \phi^j = 1$ by definition, this is equivalent to treating the remaining sources as the omitted category.

[Table 4 about here]

The comparison of the two estimation methods highlights the expected large negative bias for energy and CO2 emissions, while the bias is also large but positive for labor demand and the average wage. Sticking with our interpretation of bias in the previous section, the latter result highlights the ability of surviving establishments to endogenously adapt the technology in use in order to ease the substitution of labor for energy. Notice that absent a convincing way to evaluate the drivers of establishment's survival with our data, our estimates are conditioned on survival and thus consider only the best-performing establishments that are also more likely to innovate. By isolating only the exogenous variation in energy prices, our IV is able to replicate what would have happened if these establishments were not adapting their input mix to the new conditions.

Concerning the size of our effects, the IV estimate of the price elasticity of energy consumption is approximately -0.64. This number is larger, in absolute terms, than that estimated in sector-level studies.[21] However, when looking at micro-level estimates our results lie within the range of elasticities estimated in the existing literature.[22] Interestingly, CO2 emissions are more sensitive to energy prices than energy consumption (elasticity of -1.15 in the IV specification). This result implies that CO2-intensive establishments appear to be more price sensitive than electricity-intensive ones. As would be expected, the cross-elasticities of employment and the average wage to energy prices (-0.26 and -0.04 respectively) are much smaller than the own-elasticities estimated for energy and CO2. While the results for employment are in line with those estimated by Kahn and Mansur (2013) (-0.227 for industries with average energy intensity), the results on wages are quite new in the literature, an exception being (Walker, 2013), and deserve further comments.[23]

Note that an increase in energy prices can affect the average wage mostly through two mechanisms: i. a change in the quality of the workforce, especially in terms of skills; and ii. a decrease in the rents to be shared between workers and entrepreneurs. The first channel goes in the direction of increasing the average wage as we would expect that given the contraction in labor demand, the less-skilled workers should be fired first.[24] The second channel goes in the opposite direction: unions accept lower wages in the establishments experiencing a more stringent environmental regulation. Although we estimate a negative and significant coefficient, *de facto* the two mechanisms cancel each other out as a 10 percent increase in energy prices would decrease wages by only 0.4 percent.

Two further robustness checks are described in Appendix F: i. results conditional on firm-level changes in demand; and ii. alternative IV based on energy prices of establishments in the same decile of energy consumption and industry.

[21] See Adeyemi and Hunt (2007) for a review and estimates on 15 OECD countries and Agnolucci (2009) for estimates for Germany and the UK.

[22] The estimated implicit price elasticity of energy consumption for the UK in Martin et al. (2014) is -1.44 while the price elasticity of energy consumption for Danish firms (Bjorner and Jensen, 2002) is found to be approximately -0.46.

[23] Our results are larger than those estimated by Deschênes (2011) at the industry-state level for the US (between -0.097 and -0.156). However, looking at our FE effect results, this result can be easily explained by the fact that Deschênes (2011) cannot find a good instrument to address endogeneity problems.

[24] Evidence of a kind of skill bias in environmental technologies is provided in Vona et al. (2017), especially for engineering and technical skills. In future research, we plan to carry out a similar analysis with the French micro-data.

The first check is intended to test whether all the negative effect on employment is driven by a scale effect on output as in the related paper by Cox et al. (2014). The estimated cross-elasticity of employment to energy prices declines by 1/3 but remains statistically significant at the conventional level. The second exercise allows the exogenous variation in price to differ by the decile of energy consumption and thus capture the heterogeneous impact of reductions in quantity discounts on different establishments. Again, our results are broadly consistent with those of our preferred specification.

4.2 Heterogeneous effects

The aggregate results may hide a substantial degree of heterogeneity across different categories of the establishments' energy price shocks. We explore this likely heterogeneity by splitting our sample of firms according to a series of criteria that allow the delivery of policy-relevant messages.[25]

First and foremost, we split the sample depending on the energy intensity of the sector (2-digit NACE) to evaluate the extent to which differences in the exposure to higher energy costs affects the estimated elasticities. We use as the threshold the median value of the ratio between energy expenditure and the wage bill computed for the period 1997-2010 for all sectors (see Appendix E). Consistent with previous studies (Kahn and Mansur, 2013; Aldy and Pizer, 2015), our expectation is that more energy-intensive sectors are more sensitive to changes in energy prices than less energy-intensive sectors. The results of this exercise are reported in Table 5 and fully conform to this expectation, especially so for employment and wage. The negative and significant effect on employment and wage is present only in energy-intensive sectors, a result that is fully in line with those of previous literature (see, e.g., Kahn and Mansur, 2013). This difference is particularly large for what concerns employment: a 10-percent increase in energy prices is predicted to reduce establishment-level employment by 3.2 percent in energy-intensive sectors compared to a statistically insignificant 1.3 percent in other sectors.

[Tables 5 and 6 about here]

Second, we split the sample according to the trade intensity of sectors. The idea is that sectors that are more exposed to international competition are more sensitive to changes in energy prices: on the one hand, higher prices of intermediate inputs like energy can decrease the establishment's international competitiveness; on the other hand, sectors more open to trade more easily relocate production to countries with laxer environmental regulations (Ederington et al., 2005). We employ the trade-related criterion for exemption from auctioning of allowances in the EU ETS introduced by the European Commission at the 4-digit level (aggregated at the 3-digit level to fit our data) of the NACE (Rev. 2) classification (see Appendix E). The results split by trade intensity of the sector are reported in Table 6. Trade intensive sectors are more sensitive to

[25] An alternative approach would have been to include an interaction term between energy price and a series of continuous variables such as energy intensity (establishment- or sector-level) and trade exposure. We did not follow this approach because it would be difficult to find a convincing instrument for the interaction term. Moreover, if the variable interacted with energy prices was characterized by extreme values, these values would drive the results as the interaction term assumes linearity in the relationship.

energy prices than non-trade intensive sectors concerning energy demand and employment. This result is again expected because firms cannot easily pass the increase in unit energy cost to their customers given that the price of their final product is set on international markets.

Finally, it is interesting to note that climate policies seem equally effective in reducing CO2 both in establishments likely to be engaged in international trade and in establishments primarily serving the domestic market, although the latter achieve a given level of CO2 reduction with a smaller decrease in energy demand. This gap between reduction in energy demand and CO2 emissions may reveal different mechanisms through which emission reduction are achieved for the two groups, with the former more likely to offshoring dirty segments of the production than the latter (Cherniwchan et al., 2017). Further research exploiting firm-level data on import is required to shed light on this issue.

4.3 Simulation of policy changes

In this section, we use our estimation results to simulate the effect of a carbon price policy on the French manufacturing sector. This analysis is motivated by the fact that, on 17 August 2015, the French parliament approved the so-called 'Energy Transition Law' (*Loi relative à la transition énergétique pour la croissance verte*, loi no. 2015-992). The law sets a series of ambitious objectives for climate change mitigation that go beyond those set by the EU (i.e. the 2030 Climate and Energy Framework), such as 40-percent reduction in greenhouse gas emissions by 2030 (with respect to 1990 levels). As a main tool to achieve these ambitious goals, the law also set targets for the gradual introduction of a carbon tax: the carbon tax should have been set to 22 euro per ton of CO2 by 2016, 56 euro per ton of CO2 by 2020 and 100 euro per ton of CO2 by 2030.[26] Note that, in addition to planned carbon pricing, the tax rate of the CSPE was raised substantially after 2010 (last year in our estimates). Overall, the tax experienced a 4-fold increase (in nominal terms) for the six years after 2010, resulting in fast increase in tax-inclusive electricity price (see subsection 2.3 for details).

We use the IV-based elasticities estimated above to provide a counterfactual scenario of the environmental and economic impacts of such policies.[27] In doing so, the most important step is to simulate establishment-specific policy impacts on energy prices using the establishment-level information on energy mix and on fuel-specific CO2 intensity for year 2010. As a second step, we can straightforwardly compute the impact of the policy-induced change in energy prices on our outcome variables using our estimated elasticities (for all sub-samples (Tables 5 and 6). To aggregate across establishments, we use sampling weights for the year 2010 and thus implicitly assume no changes in technology and inter-establishment input reallocation (see next subsection).

The potential trade-off between environmental goals and labor market outcomes is evident in the Figures 10 and 11, which respectively report the effect of the low- (and of the CSPE) and high-carbon taxes. Given the price increases reported above, the predicted effects are proportional to the elasticities already reported; thus, we can focus on the policy implications of our exercise. First and

[26] As of today, the government has not complied with the commitment of introducing the carbon tax (20 euro per ton).

[27] A similar exercise is conducted by Aldy and Pizer (2015).

foremost, large emission reductions on the order of 20 percent to 40 percent (the target of the French government for the whole economy in 2030) should come at a cost in terms of employment between 5 percent and 10 percent. The trade-off is particularly stark for energy-intensive and trade-exposed industries that would experience employment losses well above 10 percent in the high-carbon tax scenario. Second, the negative employment effect can be exacerbated if a carbon tax was implemented without removing the CSPE tax. Although the two taxes target different energy sources, and thus, their effect on energy prices do not sum up, the risk of a significant loss of competitiveness for energy-intensive industries is real and should be considered in the design of the appropriate policy mix. Finally, while the two figures highlight a negligible impact on earnings, large employment losses in the ambitious scenario can translate into a decline in the workers' bargaining power and thus of wages. Also, negligible average earning losses can mask significant distributional effect that we plan to investigate in future research.

4.4 Firm-level results

We repeat our analysis when aggregating the establishment-level data to the firm level. This process allows us to add to the list of outcome variables a series of indicators of productivity. Given that energy-related information is only available for a sample of establishments, we can only keep those firm/year pairs (including single-establishment firms) for which all establishments were surveyed in the EACEI.[28] Balance sheet and income statement information, linked by means of the unique firm identifier (SIREN), is retrieved from the FICUS/FARE databases. We compute two indicators of productivity: the log of value added per employee and the log of total factor productivity (TFP).[29]

[Table 7 about here]

Table 7 contains the results of this exercise both for the outcomes variables evaluated above and for the two new measures of productivity. First of all, we observe that a more stringent environmental policy has a modest, although only barely significant, negative effect on both measures of productivity. The estimated changes predicted by a price increse of 10 percent are between -1 percent (for VA per capita) and -1.2 percent (for TFP) and are smaller than those estimated in the related paper by Greenstone et al. (2012) also using firm-level data but for a command-and-control-policy (the US Clean Air Act). This result suggests that efficiency losses are an issue to worry about in the design of climate change policy, but at the same time the results do not support the Porter Hypothesis advocating the use of environmental policies to increase

[28] As a robustness check, we also repeat our analysis by including those firms for which we were observing in EACEI establishments that accounted for at least 95, or alternatively, 90 percent of total employees in the firm. The results were confirmed and are available upon request.

[29] We estimated TFP using the semi-parametric estimator proposed by Levinsohn and Petrin (2003). TFP was estimated for the population of firms by combining information about employment level from DADS and value added and capital (built with the perpetual inventory method with sector-specific depreciation) from FICUS/FARE. The results of the estimated production functions are not reported and remain available upon request.

competitiveness.[30]

Second, the results are confirmed for employment, energy and CO2 emissions, while the elasticity on wages is of the same magnitude but imprecisely estimated. This result is surprising as we should expect at firm level there to be a reallocation of input towards less-exposed establishments. Note, however, that our sample of firms fully covered in EACEI is a sub-sample of the sample of establishments used for our main estimates. Using the same sample of establishments that belong to the sample of firms fully covered by EACEI, Table F3 in Appendix F shows that firm-level effects are, as expected, smaller in magnitude than establishment-level effects.

4.5 Within-firm relocation and estimation bounds

As already discussed in the introduction, our analysis focuses on the estimation of the causal effect of energy price on establishment level performance with no consideration of how energy price changes within an establishment influence the relocation of production activities across establishments or across sectors. However, this aspect is important for understanding how micro-level impacts translate at the more aggregate level, which is the level that is usually evaluated by policy makers when assessing the costs and benefits of their policies (Smith, 2015). This is the cost that a researcher usually pays to estimate causal effects. In particular, our establishment-level estimates implicitly assume that there is no reallocation of inputs or production across different establishments within the same industry and between industries. Such reallocation should operate in the direction of partly compensating the negative economic effect of climate policies, which means that our simulated counterfactual effects of a carbon tax are upper bounds of the actual general equilibrium effects.

As the first channel through which our effects are mitigated, establishments that are able to improve their energy efficiency and thus reduce total energy demand should become more competitive and increase their employment share. This behavior is difficult to test directly, but as a first approximation we estimate a simple correlation between the establishment-level variations in energy and labor demand (filtered by establishment fixed effects and standard controls). The resulting coefficient is modest but positive (0.11), indicating that establishments that improve their energy efficiency do not in fact grow faster than establishments that did not improve it.

A second channel is the first level of relocation that a manager would consider, that is moving production from an establishment to another one within the same company and country.[31] Different from single-establishment firms, multi-establishment firms have a larger and more resilient internal labor market as they have the possibility of choosing which establishment should be more or less engaged in production in response to, among other factors, differences in input prices across establishments (Cestone et al., 2016). More specifically,

[30] This finding is also in line with recent evidence about the impact of the EU ETS on firm performance (see e.g. Marin et al., 2017).

[31] Cestone et al. (2016) study labor reallocation across French firms belonging to the same business group, and thus, at a higher level than ours. A group-level analysis is more appropriate for studying the propagation of shocks within internal labor markets but is infeasible in our case because EACEI contains only a few firms for which establishments are fully observed. Consequently, the number of groups that are fully observed would decline at a level that makes a group-level analysis infeasible.

if a particular establishment is hit by an idiosyncratic energy price shock, the manager of a multi-establishment firm can have some margins to reduce the level of production of that establishment and at the same time to increase the production in other establishments. This change will mitigate the aggregate effect of the price shock.

Fortunately, our data display enough between-establishment within-firm variation in energy prices to estimate this relocation effect for a specific sub-sample of firms that are fully observed in the EACEI survey (but excluding single-establishment firms).[32] To illustrate, the within-firm between-establishment standard deviation in energy prices, which is the source of variation that we exploit to estimate relocation effect, is still quite large with a value of 0.168 as opposed to 0.310 for this specific sub-sample.

To evaluate and quantify within-firm reallocation, we estimate the following equation:

$$Input\_share_{i\in j,t} = \beta log(p^E_{i\in j,t}) + \gamma_{jt} + \alpha_i + \epsilon_{it}, \tag{7}$$

where $Input\_share_{i\in j,t}$ is the share of input (either energy consumption or labor) used in establishment i belonging to firm j over the total input used in firm j in year t, $log(p^E_{i\in j,t})$ is the logarithm of energy price for establishment i belonging to firm j in year t, γ_{jt} is the year-specific fixed effect for firm j, α_i is the establishment fixed effect and ϵ_{it} is the idiosyncratic error component. By conditioning on year-firm fixed effect, we consider only the within-firm variation across establishments in both the outcome variable and energy prices which is the same as considering the gap between establishment energy price and firm average energy price. Concerning the instrumental variable, we follow the same approach as for our baseline results.

The following caveat is important at this point: the results should be interpreted with particular care as these conditions imply a non-random selection of establishments, reducing the representativeness of the selected sample. Compared to the average establishment in the full sample, these establishments are 26.9 percent larger in terms of number of employees and report an energy consumption that is 97.2 percent larger.

[Table 8 about here]

The results are reported in Table 8. The results are in line with the expectations that our estimated elasticities are upper bounds of the aggregated effects of energy prices. Starting with energy, we observe that an increase in energy prices of 10 percent in establishment i reduces its share in total energy use in firm j (to which i belongs) by approximately 3.37 percent. On the other hand, the same increase in energy prices only reduces the share of labor in establishment i over total employment in firm j by 1.06 percent. This difference between

[32] In single-establishment firms, there is no scope for input reallocation. The sub-sample used in this analysis comprises the firms that satisfy the following conditions: i. all establishments of the firm were surveyed in the EACEI in year t; ii. the establishments are observed at least two times in the period 2000-2010; and iii. there is an additional observation for the establishment at least three years before the second observation (to be able to build the IV; see section 3.2). By applying these criteria, we rely on an unbalanced panel of 1,334 establishments that belong to 571 firms.

energy and labor can be associated with two different explanations. First, similar to what was observed in our baseline results (Table 4), energy consumption is more sensitive to energy prices than employment. Secondly, energy as an input is more mobile than labor: firms will not easily move workers from one establishment to the other while increasing production and consequently energy use in a specific establishment is easier for the firm.

5 Conclusions

Our paper provides evidence on the link between energy prices and various measures of economic and environmental performance for a panel of French manufacturing establishments. After discussing the features of the French manufacturing sector in terms of energy use and energy prices and the main policy changes occurred within the estimation period, we build an empirical framework that is suited to deal with potential endogeneity of energy prices and estimate their impact on different performance variable.

Our results identify a trade-off between environmental and economic goals due to changing energy prices. We estimate that a 10-percent increase in establishment-level energy prices brings to a 6.4 percent reduction in energy consumption and to a 11.5 percent reduction in CO2 emissions. At the same time, the same 10-percent increase in energy prices has a modest negative impact on employment (-2.6 percent) and an even smaller effect on wages (-0.4 percent) and on firm's productivity (-1.1 percent). The negative employment effect differ across sectors depending on their energy intensity and their exposure to international trade, with the effect being larger in magnitude for energy-intensive and trade-exposed sectors. Simulating the effect of a carbon tax, we show that job losses for the most exposed sectors can be quite large and, in absence of compensating labor market policies, may justify the opposition of specific lobbies to climate change policies.

Our approach focuses on just one dimension of the impact of environmental regulation on environmental and economic performance, as we do not consider the consequences of reallocation of inputs and production across establishments (within sector) with different energy prices and we also shut down the possibility of structural change induced by changing energy prices. When considering within-firm between-establishment reallocation of inputs in response to energy price changes, we observe that there exists a substantial shift of inputs towards less exposed establishments. This preliminary analysis leads us to think that the estimated negative effect of climate policies on employment is an upper bound, but obviously further research is required in this direction.

Further research is also needed in this framework to provide a more comprehensive picture of the different mechanisms through which changing energy prices translate in macro-level changes in environmental and economic performance. Our focus here is on the most disaggregated unit of analysis, that is the establishment. The reallocation of inputs and output across establishments within the same sector would require very detailed data on the population of establishments (of firms) within a sector and the use of decomposition techniques similar to the ones used to estimate aggregate total factor productivity growth from microdata (see e.g. Petrin and Levinsohn, 2012). On the other hand, general equilibrium modelling is required to provide evidence about the relevance of structural change induced by changing energy prices.

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Tables and figures

Table 1: Sector-level information

Sector		Energy expend / wages	Average energy price per kWh	Average electr price per kWh	Average gas price per kWh	Average electr share	Average gas share
13	Textiles	0.323	0.048	0.068	0.03	0.497	0.347
		(0.524)	(0.018)	(0.018)	(0.010)	(0.317)	(0.351)
14	Wearing apparel	0.081	0.061	0.081	0.033	0.531	0.24
		(0.173)	(0.021)	(0.018)	(0.012)	(0.307)	(0.311)
15	Leather and related products	0.086	0.059	0.078	0.035	0.557	0.196
		(0.174)	(0.018)	(0.018)	(0.011)	(0.264)	(0.278)
16	Wood and of products of wood and cork	0.338	0.064	0.074	0.034	0.736	0.073
		(0.619)	(0.019)	(0.019)	(0.012)	(0.258)	(0.191)
17	Paper and paper products	0.284	0.049	0.066	0.03	0.509	0.321
		(0.507)	(0.019)	(0.019)	(0.011)	(0.276)	(0.313)
18	Coke and refined petroleum products	0.197	0.061	0.071	0.034	0.728	0.195
		(0.390)	(0.017)	(0.017)	(0.011)	(0.248)	(0.239)
20	Chemicals and chemical products	0.378	0.047	0.064	0.03	0.475	0.335
		(0.884)	(0.019)	(0.019)	(0.011)	(0.292)	(0.324)
21	Basic pharmaceutical products	0.144	0.046	0.058	0.029	0.555	0.37
		(0.277)	(0.014)	(0.013)	(0.009)	(0.227)	(0.256)
22	Rubber and plastic products	0.238	0.055	0.064	0.033	0.721	0.177
		(0.391)	(0.016)	(0.017)	(0.011)	(0.286)	(0.263)
23	Other non-metallic mineral products	0.367	0.049	0.067	0.028	0.471	0.294
		(0.590)	(0.021)	(0.018)	(0.010)	(0.320)	(0.356)
24	Basic metals	0.381	0.046	0.062	0.029	0.5	0.342
		(0.619)	(0.017)	(0.017)	(0.009)	(0.258)	(0.294)
25	Fabricated metal products	0.207	0.059	0.074	0.034	0.628	0.237
		(0.451)	(0.017)	(0.018)	(0.011)	(0.272)	(0.279)
26	Computer, electronic and optical products	0.127	0.061	0.072	0.034	0.727	0.194
		(0.683)	(0.019)	(0.020)	(0.011)	(0.272)	(0.254)
27	Electrical equipment	0.135	0.056	0.071	0.033	0.605	0.289
		(0.358)	(0.017)	(0.018)	(0.010)	(0.270)	(0.285)
28	Machinery and equipment n.e.c.	0.144	0.058	0.077	0.035	0.524	0.317
		(0.310)	(0.018)	(0.019)	(0.011)	(0.266)	(0.304)
29	Motor vehicles, trailers and semi-trailers	0.164	0.054	0.072	0.033	0.543	0.297
		(0.368)	(0.016)	(0.020)	(0.010)	(0.261)	(0.292)
30	Other transport equipment	0.101	0.054	0.072	0.033	0.523	0.345
		(0.315)	(0.017)	(0.019)	(0.010)	(0.258)	(0.290)
31	Furniture	0.205	0.062	0.077	0.034	0.634	0.191
		(0.359)	(0.018)	(0.017)	(0.010)	(0.297)	(0.290)
32	Other manufacturing	0.112	0.062	0.077	0.035	0.655	0.227
		(0.187)	(0.019)	(0.019)	(0.012)	(0.287)	(0.280)
33	Repair and installation	0.156	0.068	0.086	0.037	0.606	0.213
		(0.399)	(0.019)	(0.019)	(0.011)	(0.312)	(0.293)
	Total	0.217	0.057	0.072	0.033	0.601	0.251
		(0.482)	(0.019)	(0.019)	(0.011)	(0.293)	(0.297)

Standard deviation in parenthesis. Own elaboration on EACEI and DADS data. Information refers to the period 1997-2010 and is weighted by sampling weights across establishments.

Table 2: Impact of policies on energy prices and energy mix

	(1) $\log(p^E)$	(2) $\log(p^E)$	(3) $\log(p^E)$	(4) $\log(p^E)$	(5) Electr share	(6) Gas share
PMR	0.122***			0.118***		
(1: regulated; 0: unregulated)	(0.0103)			(0.0103)		
Firm-specific CSPE (euro/MWh)		-18.24***		-8.800***	-4.489**	13.03***
		(2.916)		(2.994)	(1.882)	(2.451)
ETS x D(2001-2004)			0.0898***	0.0741***	0.000308	0.0205*
			(0.0125)	(0.0124)	(0.00614)	(0.0122)
ETS x D(2005-2007)			0.173***	0.151***	0.00310	0.00445
			(0.0175)	(0.0179)	(0.0104)	(0.0184)
ETS x D(2008-2010)			0.209***	0.190***	0.0110	0.000471
			(0.0189)	(0.0193)	(0.126)	(0.0211)
N	115639	115639	115639	115639	115639	115639

Fixed effect model. Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional control variables: year-sector (2-digit NACE rev 2), year-region (NUTS2) dummies, year-ETS dummies, year-peak (>Q3) dummies, year-size (initial size classes) dummies. Sample: establishment that are observed in EACEI for at least two years

Table 3: Differences in employment patterns for establishments with different initial energy mix

Dep var: log(empl)	(1)	(2)
Initial electricity share x D1998	0.0200	0.00151
	(0.0147)	(0.0155)
Initial electricity share x D1999	0.0219	-0.00515
	(0.0215)	(0.0228)
Initial electricity share x D2000	0.0798***	0.0277
	(0.0225)	(0.0237)
Initial electricity share x D2001	0.0780**	0.0329
	(0.0317)	(0.0335)
Initial gas share x D1998	0.0120	0.00742
	(0.0143)	(0.0148)
Initial gas share x D1999	-0.000556	-0.00402
	(0.0199)	(0.0203)
Initial gas share x D2000	0.00478	-0.00901
	(0.0222)	(0.0223)
Initial gas share x D2001	0.00289	0.000620
	(0.0309)	(0.0310)
N	43070	43070
F test: joint significance of electr share	4.078	0.817
p-value	0.00264	0.514
F test: joint significance of gas share	0.279	0.265
p-value	0.892	0.901
F test: joint significance of electr and shares	3.180	1.008
p-value	0.00133	0.427

Fixed effect model. Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Year dummies included. Additional control variables included in column (2): year-sector (2-digit NACE rev 2), year-region (NUTS2) dummies, year-ETS dummies, year-peak (>Q3) dummies, year-size (initial size classes) dummies. Sample: establishment in EACEI 1997 that were observed in DADS in all years for the period 1997-2001

Table 4: Baseline results

	log(energy cons)		log(CO2)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-1.218***	-0.644***	-1.735***	-1.149***
	(0.0308)	(0.0780)	(0.0553)	(0.117)
F excl IV first stage		1393.9		1151.0
N	61153	61153	54437	54437
	log(empl)		log(average wage per empl)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-0.0742***	-0.263***	-0.00267	-0.0445**
	(0.0152)	(0.0593)	(0.00399)	(0.0174)
F excl IV first stage		1393.9		1423.2
N	61153	61153	59076	59076

Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional control variables: year-sector (2-digit NACE rev 2), year-region (NUTS2) dummies, year-ETS dummies, year-peak (>Q3) dummies, year-size (initial size classes) dummies. Sample: establishment that are observed in EACEI for at least two years and observations three years or more after the first year in EACEI (used to build the initial energy mix for the IV). Excluded IV: log of national energy prices (by source) weighted with initial energy mix of the plant.

Table 5: Results by energy intensity of the sector

	Energy intensive sectors			
	log(energy cons)		log(CO2)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-1.226***	-0.680***	-1.732***	-1.205***
	(0.0437)	(0.0964)	(0.0797)	(0.144)
F excl IV first stage		855.1		716.7
N	32864	32864	28967	28967
	log(empl)		log(average wage per empl)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-0.0757***	-0.318***	-0.000684	-0.0524**
	(0.0180)	(0.0683)	(0.00514)	(0.0211)
F excl IV first stage		855.1		912.0
N	32864	32864	31835	31835
	Non energy intensive sectors			
	log(energy cons)		log(CO2)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-1.198***	-0.462***	-1.732***	-0.984***
	(0.0399)	(0.133)	(0.0646)	(0.205)
F excl IV first stage		534.5		436.3
N	28289	28289	25470	25470
	log(empl)		log(average wage per empl)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-0.0687**	-0.130	-0.00628	-0.0246
	(0.0268)	(0.114)	(0.00638)	(0.0308)
F excl IV first stage		534.5		503.2
N	28289	28289	27241	27241

Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional control variables: year-sector (2-digit NACE rev 2), year-region (NUTS2) dummies, year-ETS dummies, year-peak (>Q3) dummies, year-size (initial size classes) dummies. Sample: establishment that are observed in EACEI for at least two years and observations three years or more after the first year in EACEI (used to build the initial energy mix for the IV). Excluded IV: log of national energy prices (by source) weighted with initial energy mix of the plant.

Table 6: Results for trade intensive and non trade intensive sectors

	Trade intensive sectors			
	log(energy cons)		log(CO2)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-1.247***	-0.790***	-1.649***	-1.146***
	(0.0540)	(0.124)	(0.0913)	(0.174)
F excl IV first stage		573.0		491.2
N	24461	24461	22189	22189
	log(empl)		log(average wage per empl)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-0.0844***	-0.308***	-0.00467	-0.0420
	(0.0247)	(0.100)	(0.00626)	(0.0295)
F excl IV first stage		573.0		559.8
N	24461	24461	23604	23604
	Non trade intensive sectors			
	log(energy cons)		log(CO2)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-1.202***	-0.538***	-1.796***	-1.122***
	(0.0371)	(0.104)	(0.0649)	(0.166)
F excl IV first stage		724.1		578.7
N	36692	36692	32248	32248
	log(empl)		log(average wage per empl)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-0.0613***	-0163**	-0.000307	-0.0521**
	(0.0194)	(0.0770)	(0.00518)	(0.0223)
F excl IV first stage		724.1		764.8
N	36692	36692	35472	35472

Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional control variables: year-sector (2-digit NACE rev 2), year-region (NUTS2) dummies, year-ETS dummies, year-peak (>Q3) dummies, year-size (initial size classes) dummies. Sample: establishment that are observed in EACEI for at least two years and observations three years or more after the first year in EACEI (used to build the initial energy mix for the IV). Excluded IV: log of national energy prices (by source) weighted with initial energy mix of the plant.

Table 7: Results for firm-level measures

	log(energy cons)		log(CO2)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-1.221***	-0.528***	-1.838***	-1.049***
	(0.0434)	(0.113)	(0.0700)	(0.178)
F excl IV first stage		829.9		619.2
N	30600	30600	26738	26738
	log(empl)		log(average wage per empl)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-0.0915***	-0.262***	0.00655	-0.0447
	(0.0143)	(0.0447)	(0.0172)	(0.0580)
F excl IV first stage		813.4		804.1
N	30355	30355	30045	30045
	log(VA / empl)		log(TFP)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-0.0154	-0.106	-0.0302	-0.122
	(0.0224)	(0.0845)	(0.0206)	(0.0793)
F excl IV first stage		806.9		795.4
N	29862	29862	29438	29438

Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional control variables: year-sector (2-digit NACE rev 2), year-region (NUTS2) dummies, year-ETS dummies, year-peak (>Q3) dummies, year-size (initial size classes) dummies. Excluded IV: log of national energy prices (by source) weighted with initial energy mix of the plant. Sample: firms for which all plants are included in EACEI and that are observed in EACEI for at least two years and observations three years or more after the first year in EACEI (used to build the initial energy mix for the IV).

Table 8: Within-firm relocation

	Establishment share of firm energy consumption		Establishment share of firm employment	
	FE	FE-IV	FE	FE-IV
log(energy price)	-0.374***	-0.337***	-0.0718***	-0.106**
	(0.0343)	(0.0622)	(0.0214)	(0.0420)
F excl IV first stage		140.5		137.0
N	5217	5217	5144	5144

Fixed effect model. Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional control variables: firm-year dummies. Excluded IV: log of national energy prices (by source) weighted with initial energy mix of the plant. Sample: plants in multi-plant firms for which all plants are observed in EACEI; plants that are observed in EACEI for at least two years.

Figure 1: Average electricity price (euro per MWh) for industrial customers by yearly consumption band (year 2010, source: Eurostat)

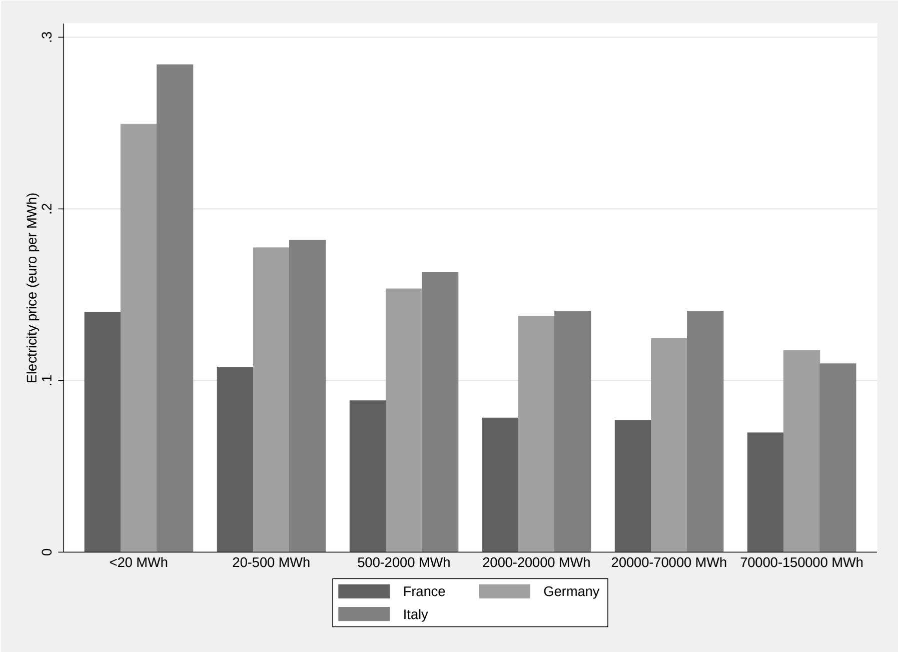
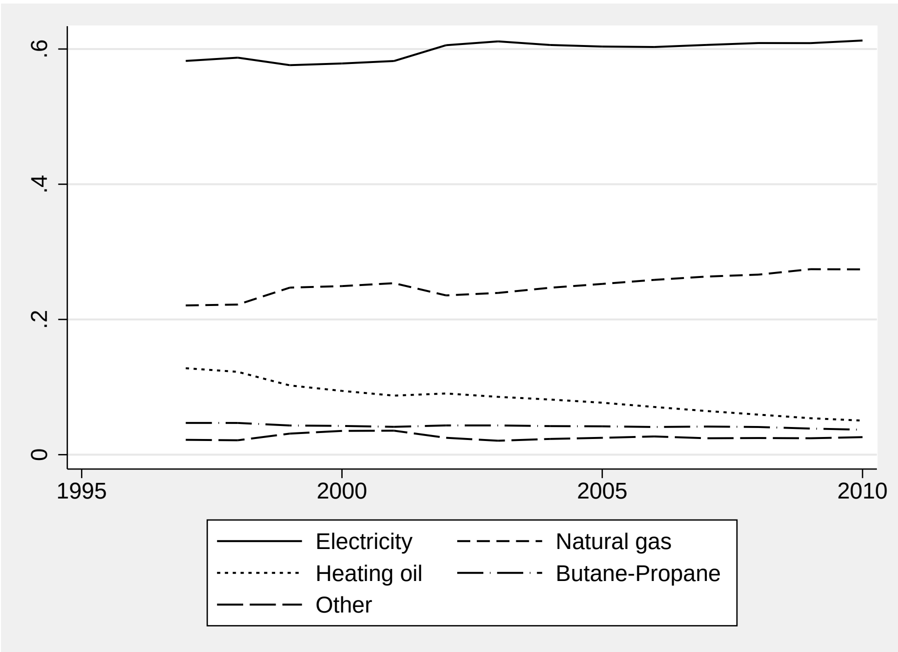
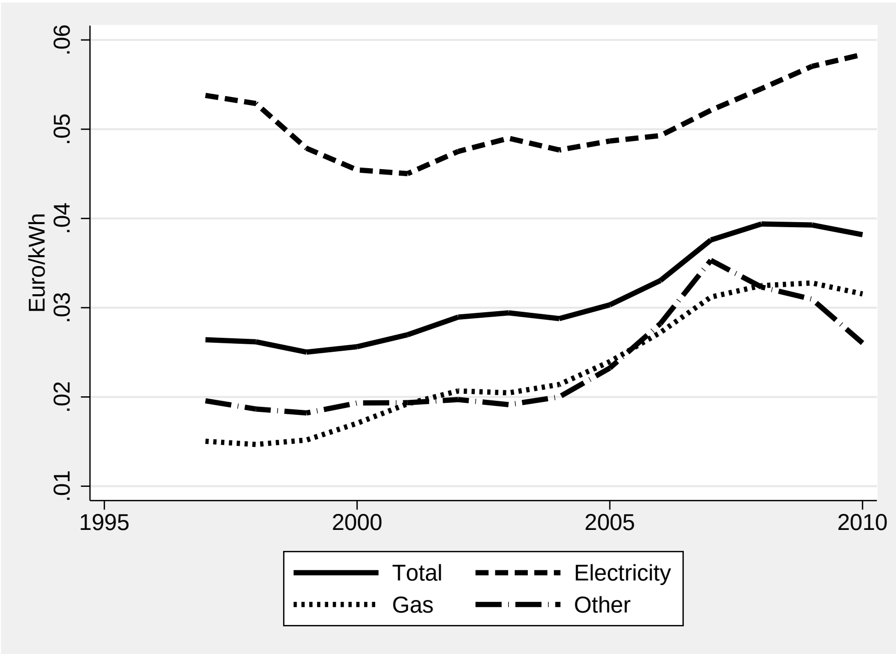


Figure 2: Average energy mix of French manufacturing establishments



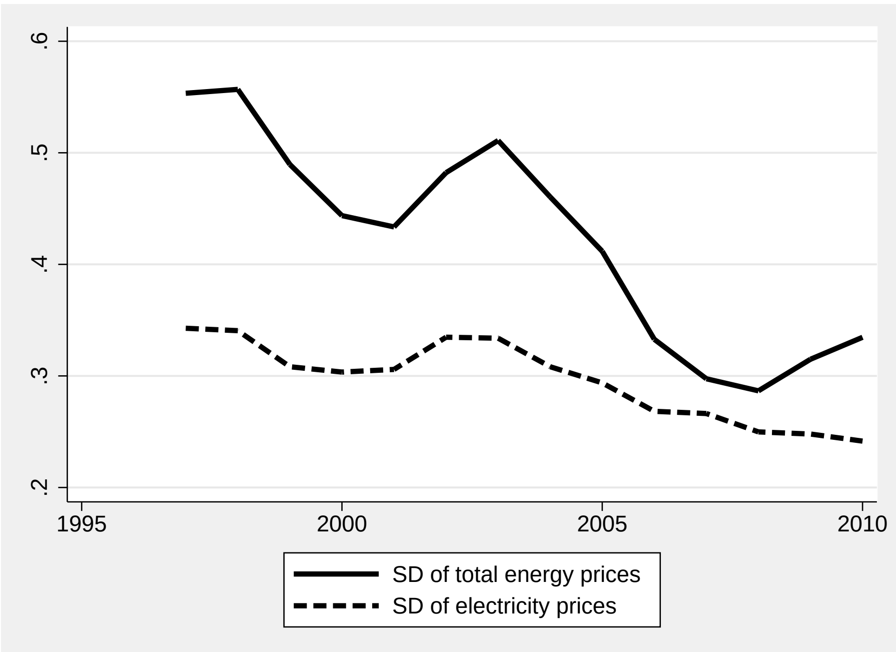
Own elaboration on EACEI data. Average energy mix weighted by sampling weights. The 'Other' category includes: heavy oil, oil, steam, coke, other gas, coke-petrol, lignite.

Figure 3: Average energy prices of French manufacturing establishments



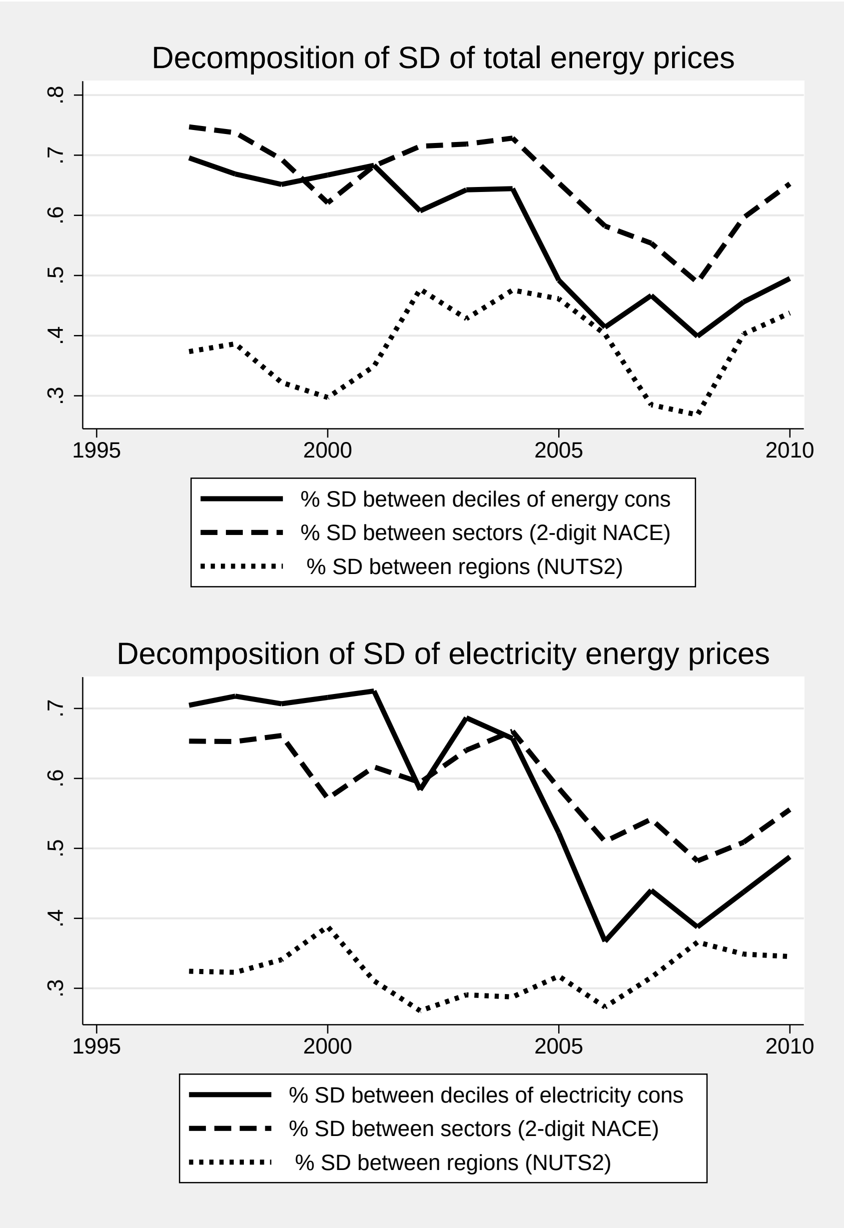
Own elaboration on EACEI data. Average energy prices weighted by sampling and energy consumption weights.

Figure 4: Standard deviation of establishment-level log energy prices (total and electricity)



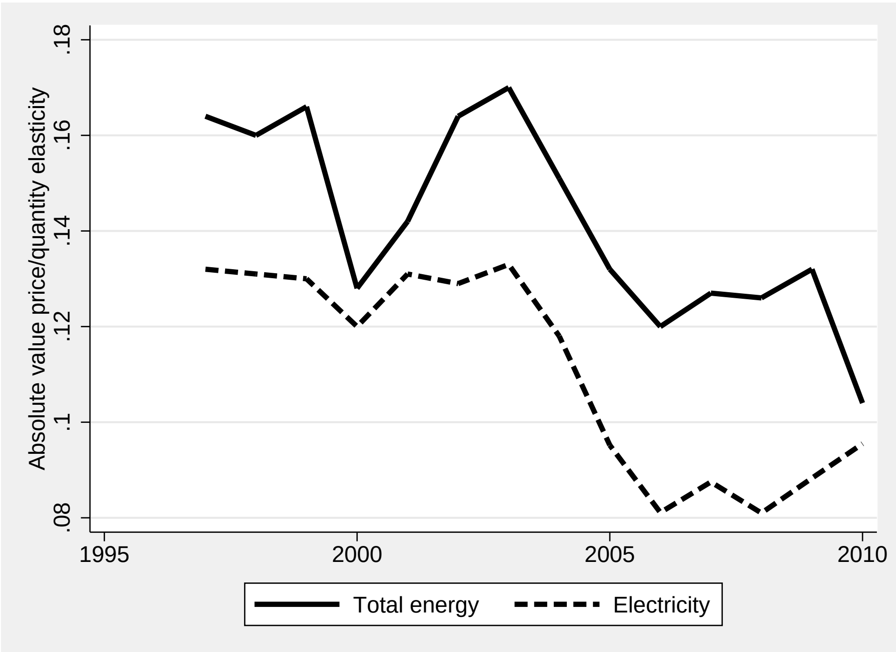
Own elaboration on EACEI data. Year-by-year standard deviation weighted by sampling and energy consumption (total and electricity, respectively) weights.

Figure 5: Decomposition of standard deviation of establishment-level log energy prices (total - upper panel - and electricity - lower panel)



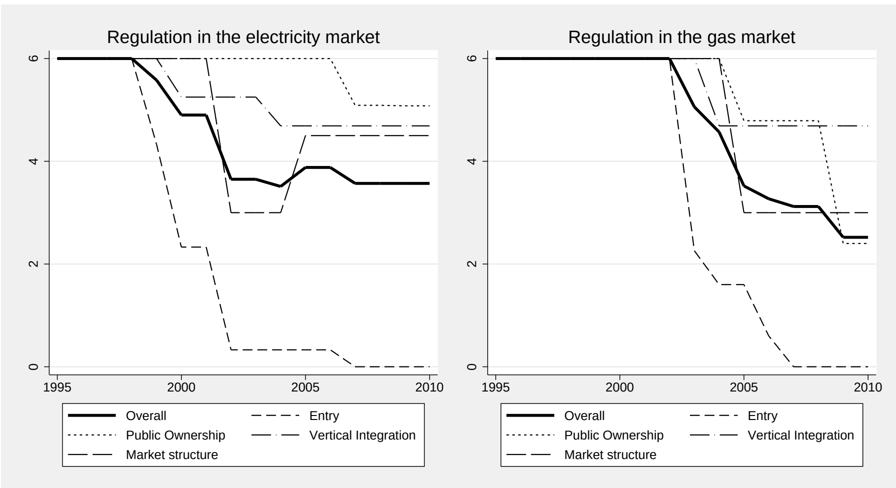
Own elaboration on EACEI data. Ratio between year-by-year standard deviation across categories and overall standard deviation, weighted by sampling and energy consumption (total and electricity, respectively) weights.

Figure 6: Quantity discount for energy (total and electricity)



Own elaboration on EACEI data. Year-by-year elasticity (absolute value) of energy price with respect to energy consumption conditional on sector dummies (2-digit NACE) and region dummies (NUTS2). Regressions are weighted by energy consumption and sampling weights.

Figure 7: Product market regulation index in the electricity (left) and gas (right) sectors



Own elaboration on OECD data.

Figure 8: Predicted impact on average energy prices of policy changes (carbon tax of 56 euro per ton of CO2 and CSPE of 22.5 euro per MWh)

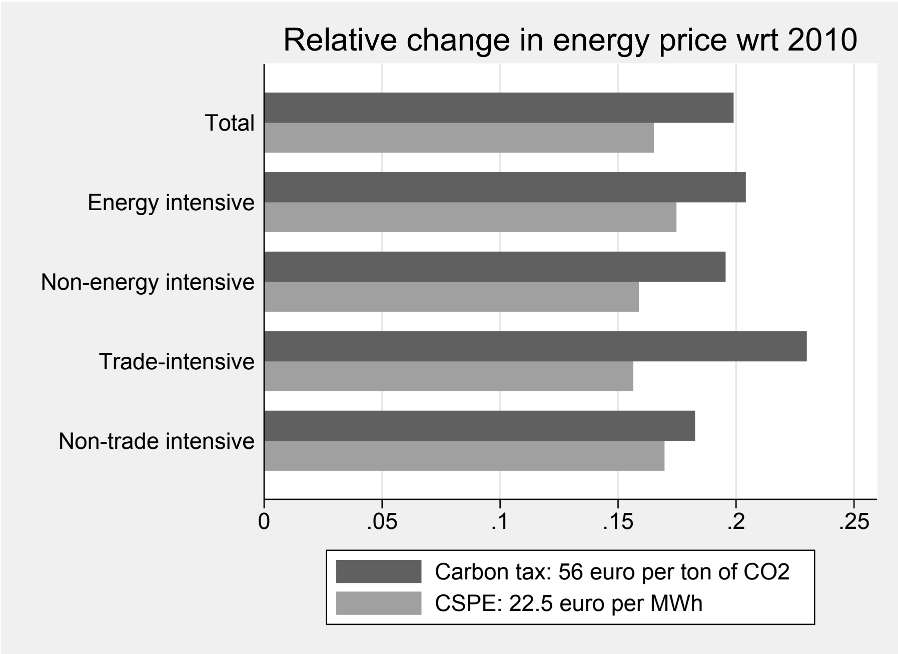


Figure 9: Predicted impact on average energy prices of policy changes (carbon tax of 100 euro per ton of CO2)

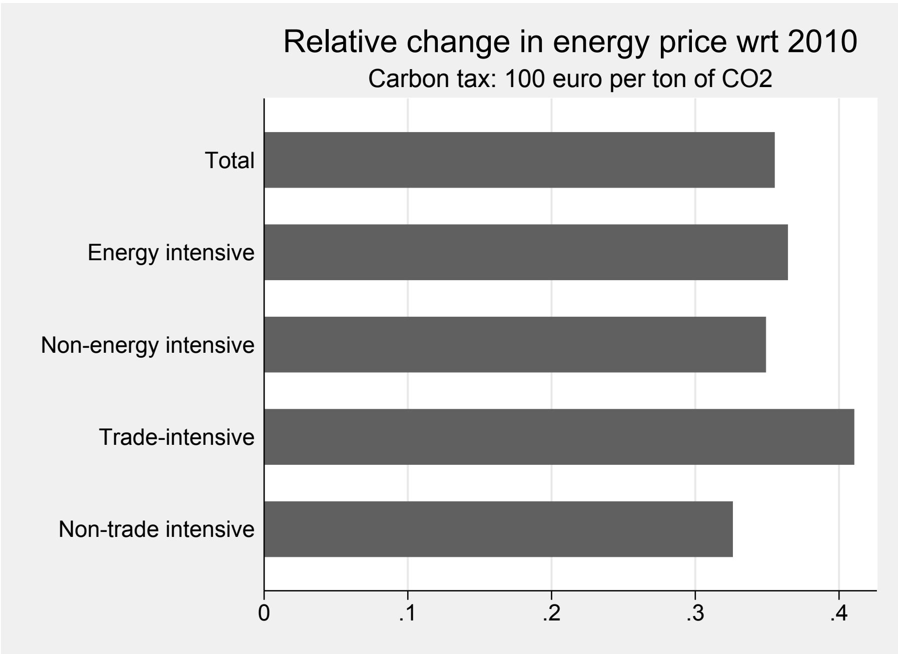


Figure 10: Predicted impact on outcome variables of policy changes (carbon tax of 56 euro per ton of CO2 and CSPE of 22.5 euro per MWh)

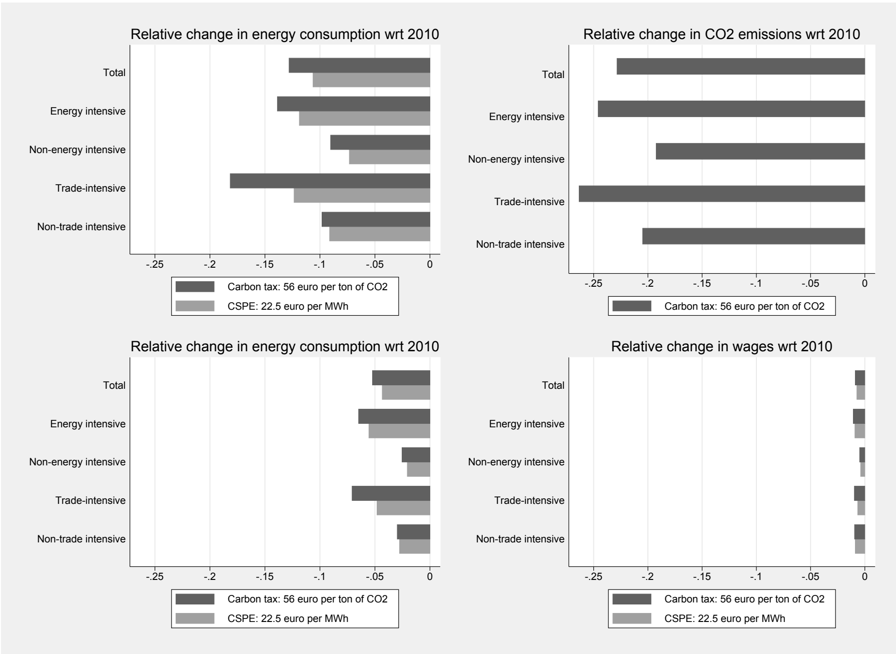
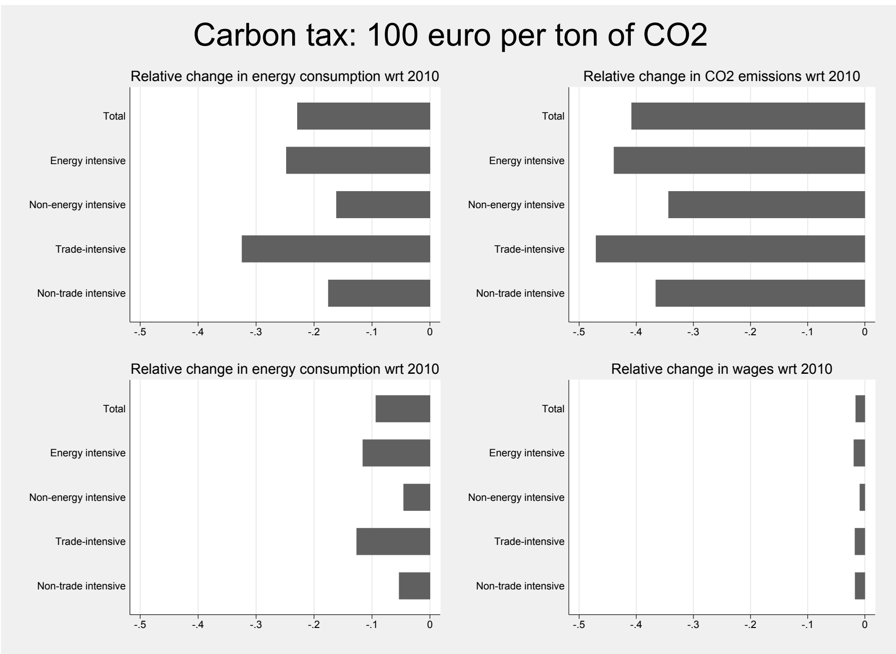


Figure 11: Predicted impact on outcome variables of policy changes (carbon tax of 100 euro per ton of CO2)



A Data sources

The main source of data is the EACEI survey. The EACEI (Enquête sur les consommations d'énergie dans l'industrie) is a survey to manufacturing establishments that provides information on energy consumption (quantity and value) broken down by energy type: electricity (consumed and auto-produced), steam, natural gas, other types of gas, coal, lignite, coke, propane, butane, heavy fuel oil, heating oil and other petroleum products.[33] In the first part of our period (1997-2010), sectors 10-12 (Manufacture of food products, beverages and tobacco products, NACE Rev 2) were not included in the survey design. We thus exclude establishments in these sectors also in the second part of our panel. From 2007 onwards, other non-manufacturing industrial sectors were included (e.g. 38.3 'Material recovery'). We also exclude these additional non-manufacturing sectors. All establishments with more than 250 employees are requested to participate to the survey (Wagner et al., 2014, plus all establishments with more than 10 or 20 employees in specific energy-intensive sectors, see[for further details) while only a sample establishments with 20 or more employees is interviewed. The response rate is nearly 90 percent.

Information on establishment-level total wages paid and average wages were retrieved form the DADS (Déclaration Annuelle des données Sociales) database, that is an administrative collection of data on employment and wages for the population of French establishments. We linked information in EACEI with information in DADS by means of the unique identifier of French establishments (SIRET).

Balance sheet information for French firms was retrieved from the FICUS (Fichier de comptabilité unifié dans SUSE, 1997-2007) and FARE (Fichier approché des résultats d'Esane 2008-2010) databases, that contain information on balance sheets and income statements for the population of French firms. Firm-level data from FICUS/FARE were linked to EACEI and DADS based on the unique identifier of French firms (SIREN).

B Characteristics of the estimation sample

The characteristics of the estimation sample that we employed in our baseline results are reported in Table B1. Overall, the largest possible estimation sample for the period 2000-2010 consisted of 89769 observations (establishment/year). Our estimation sample for total energy and employment included 61153 observations, that is about 68 percent of the total. These selected observations represent 68.1 percent of the total number of possible observations but account for as much as 73 percent of energy consumption and 74 percent of employment (see Table B1).

[Table B1 about here]

[33]For what concerns auto-produced of electricity, our measure of total energy consumption accounts for the fuels employed in self production while it does not consider electricity self-produced to avoid double counting. Over total electricity consumption (purchased from the grid and self produced), self produced electricity only accounts for 6.6 percent. Overall, self produced electricity represents more than 1 percent (10 percent) of total electricity use for 4.5 percent (1.7 percent) of establishment-year pairs.

To gain a more precise understanding of the bias brought about this sample selection, we regress a series of variables on a dummy variable that equals one for observations in the selected sample and zero otherwise. Results are reported in Table B2. Conditional on year dummies, selected establishments are larger in terms of employees (39.1 log points, 47.8 percent), consume more energy (113.8 log points, 212.1 percent) and are more energy intensive in terms of energy consumption per worker (74.8 log points, 111.3 percent). On average, conditioning on total energy consumption (to account for quantity discounts), energy prices were smaller in selected establishments (2.3 log points, 2.3 percent). A slightly larger difference (3.2 log points, 3.1 percent) is estimated for electricity prices (conditioning here on total electricity consumption).

[Table B2 about here]

C Further results on the dynamics of quantity discounts

We further refine our assessment of the elasticity of energy price to quantity by estimating an econometric model that accounts for establishment fixed effects, α_i, and directly allows testing for the significance in the elasticity changes:

$$\begin{aligned} \log(p^E_{it}) &= \alpha_i + \sum_{s=1998}^{2010} \beta_s \log(Energy\_use_{i,t=0}) \times D_s + \\ &+ X'_{it}\gamma + \epsilon_{it}, \end{aligned} \quad (8)$$

where $\log(p^E_{it})$ is the average unit cost of energy (in log) in year t for establishment i, $\log(Energy\_use_{i,t=0})$ is the logarithm of energy consumption of establishment i in the first year in which the establishment is observed in EACEI, D_s is a dummy variable that equals one in year s, ϵ_{it} is the idiosyncratic error term and X_{it} is a vector of control variables that account for a variety of unobserved year-specific effects[34]. Using 1997 as the base year, $\hat{\beta_s}$ represent the within-establishment change in the elasticity of electricity prices to quantity between 1997 and year s. Positive values indicate a reduction in the quantity discount.

[Figure C1 about here]

Estimated $\hat{\beta_s}$ are reported in Figure C1 (with 95 percent confidence intervals). Results suggest that quantity discounts for electricity remained constant up to year 2001 and decreased significantly thereafter. More specifically, in 2006 the quantity discount decreased of approximately 3 percentage points with respect to the base year (2.1 percent in 2010). These estimates implies that an important fraction of the reduction in quantity discount occurred within establishments rather than being associated to within-sector compositional change or to the fact that above-average prices are charged to new establishments.

[34] We interact year dummies with the following set of dummies: sector dummies (NACE rev 2, 2 digit), region dummies (NUTS2) and ETS dummies (equal to 1 for establishments covered by the EU ETS).

D Discontinuity in CSPE and impact on electricity prices

The CSPE tax creates a partial discontinuity in the schedule of marginal tax but does not create any discontinuities in the distribution of the average tax per MWh, thus avoiding potential distortions due to strategic behaviours. We check for the presence of a possible discontinuity in the relationship between the level of energy consumption and energy prices around the level of energy consumption (in MWh/year) beyond which each additional kWh of electricity purchased is exempted from the CSPE.[35] We evaluate the presence of a discontinuity by fitting a linear relationship between energy consumption (100 Mhw above and below the threshold) and prices for 2000 (before the CSPE), 2003 (second year of the CSPE), 2004 (year in which the tax rate has increased to 4.5 euro/MWh, moving the threshold for exemption) and 2010 (last year of the dataset). We allow the linear relationship to differ below and above the threshold.

[Figure D1 about here]

If anything, we should expect that tax-inclusive electricity prices just above the threshold should be systematically smaller than just below the threshold. Results, reported in Figure D1, point to the opposite direction: while no significant discontinuity is found in 2000 (as expected) and 2003, the discontinuity is statistically significant for 2004 and 2010 but at odds with our expectations. Tax-inclusive electricity prices just above the threshold in these years are greater than just below the threshold. This striking result, that is consistent with the observed reduction in the heterogeneity of electricity prices (Figure 4) and the decreasing size of quantity discount (Figure 6), suggests that EDF completely incorporated in its tax-inclusive tariffs the average value of the tax and, at the same time, decided to increase (in relative terms) the price charged to large industrial consumers of electricity. Overall, the various different descriptive evidences discussed above point to a counter-intuitive effect of the CSPE: despite partial exemptions for large consumers of electricity, the change of the pre-tax price structure of electricity more than compensated the impact of the exemption from the CSPE.

E Energy intensive and trade intensive sectors

To identify energy-intensive sectors, we compute the average ratio between establishment-level energy expenditure and establishment-level total wages for each 2-digit NACE sector. We compute the average by weighting for the relative importance of each establishment within the sector in terms of wages paid. Sectors above the median of relevance of energy expenditure are identified as energy intensive. The full list of 2-digit NACE sectors broken down by energy intensity is reported in Table E1.

[Table E1 about here]

[35] As the overall plafond is fixed and the tax rate changes over time, the threshold in terms of electricity consumption above which the marginal tax collapses to zero changes in time

To identify trade-intensive sectors we employ one of the criteria used by the European Commission to exempt from auctioning of allowances (from the third phase 2013-2020) establishments in those sectors that were deemed to be at risk of carbon leakage (Decision 2010/2/EU, amended by the Decisions 2012/498/EU and 2014/9/EU). These criteria considered the CO2 emission intensity of the sector and its exposure to extra-EU28 trade. We identify trade-intensive sectors those for which trade (import plus export) with non-EU28 countries is larger than 10 percent of the total EU28 production in that sector.[36]. A comprehensive evaluation of the link between exposure to carbon leakage and effective risks of job losses is done by Martin et al. (2014).

[Table E2 about here]

F Robustness checks

As a first robustness check, we want to see if our estimated elasticities are fully driven by a scale effect. For instance, as in Cox et al. (2014), the negative effect of energy prices on employment can be fully mediated by a negative effect of energy prices on the scale of firm operation. The same argument holds for energy demand. Our proxy of scale is the value of firm production (turnover). Notice that this is not our favourite estimate for two important reasons. First, our proxy of scale is likely to be endogenous as energy and labor inputs directly influence firm-level production and turnover. Second, we can only observe turnover for firms and not for each establishment. Results are reported in Table F1. As expected, for all outcome variables except average wages, accounting for turnover results in a small reduction in the magnitude of estimated elasticities of outcome variables to energy prices. This result suggests that part of the overall effect estimated in our main specification are explained by an induced scale effect.

[Table F1 about here]

Using a lag of three years in computing the energy mix for our IV may not be enough to ensure the exogeneity of the instrument as the energy mix is very persistent within establishment. As a second sensitivity test, we build an alternative IV that is not based on establishment-specific data but exploits more general systematic difference across establishments belonging to different deciles of total energy consumption and industries. For each decile of energy consumption and sector (2-digit NACE), we compute the average energy mix for years 1997-1999. The idea is that, for technological reasons, firms belonging to different sectors and, within the sector, to different deciles of energy consumption should be characterized by a reduced set of viable technological choices in terms of energy mix. We then use this estimated energy mix to compute the weighted average of energy prices for each cell decile of energy consumption-sector and each year.

[Table F2 about here]

[36]The list is available at: https://ec.europa.eu/clima/policies/ets/allowances/leakage_en (last accessed: July 2017)

Results are reported in Table F2. Across the board, estimated elasticities with this new IV appear to be slightly smaller than the ones estimated in Table 4 and the precision of estimates is also lower (i.e. higher standard errors) due to the weaker correlation between the IV and the endogenous variable. The difference in point coefficients is particularly large for CO2 emissions, while the elasticity of average wages per employees is now not statistically different from zero. It should be noted, however, that these results are not statistically different from the ones arising from our baseline estimates.

[Table F3 about here]

Another robustness check consists in providing a benchmark of establishment-level estimates for the sample of firms that were analyzed in the firm-level analysis of section 4.4. Results for this sub-sample are reported in Table F3 and suggest that, with the exception of CO2 emissions, the magnitude of estimated point coefficients is larger for establishment-level than for firm-level estimates.

Tables and figures of appendixes

Table B1: Characteristics of the estimation sample

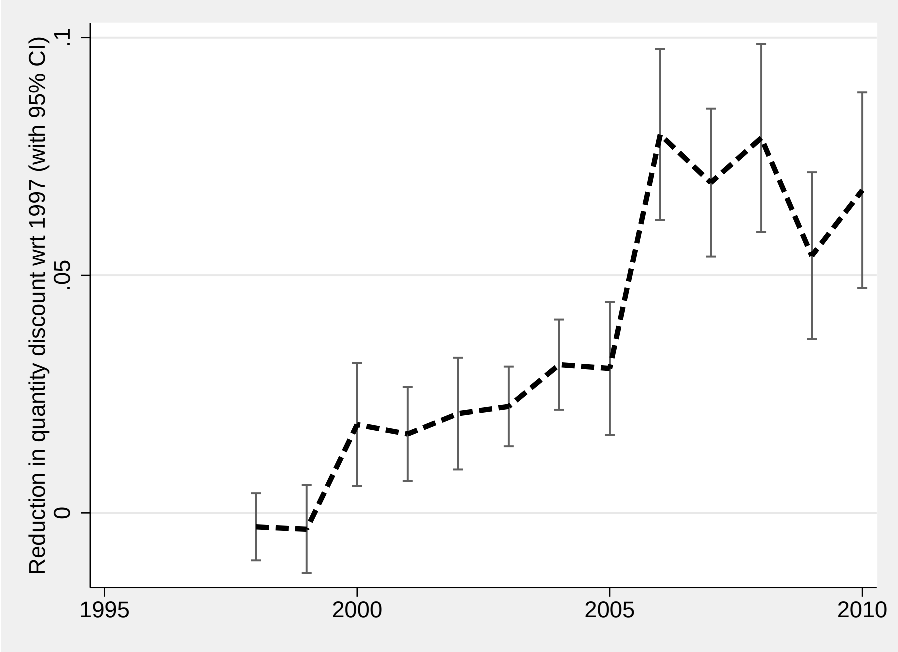
Potential number of observations (2000-2010)	89769
Observations in the estimation sample	61153
Share of 'selected' observations over total observations	0.6812
Share of energy consumption in 'selected observations' (over total energy consumption)	0.7296
Share of labor in 'selected' observations (over total labor)	0.7371

Table B2: Differences between estimation sample and overall population

Dep var	log(empl)	log(ener cons)	log(ener cons / L)	log(energy price)	log(electr price)
Dummy: selected sample	0.391***	1.138***	0.748***	-0.0231***	-0.0316***
	(0.0106)	(0.0224)	(0.0188)	(0.00319)	(0.00295)
log(ener consumption)				-0.124***	
				(0.00102)	
log(electr consumption)					-0.0101***
					(0.000938)
N	89796	89796	89796	89796	89796

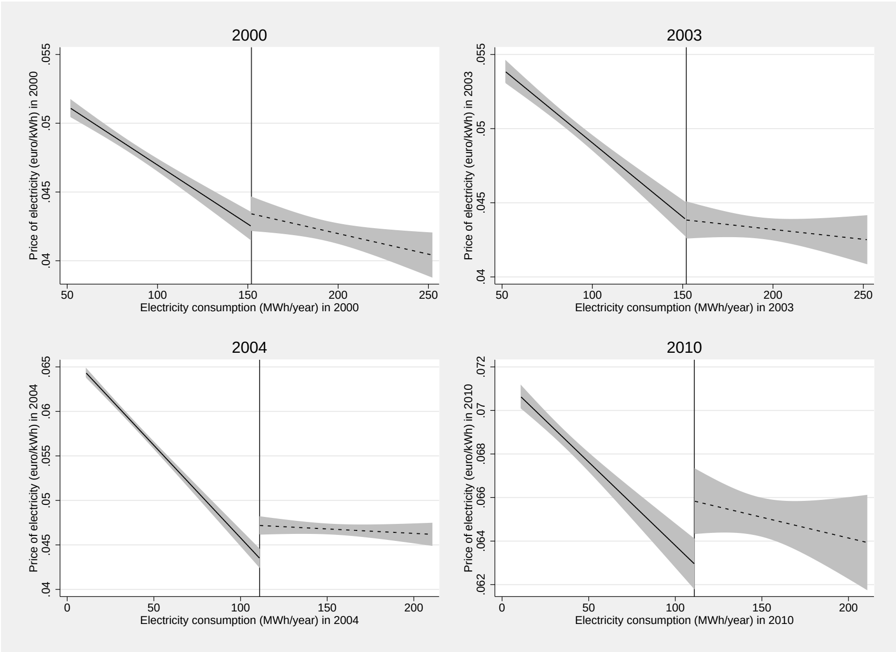
OLS pooled model weighted with sampling weights. Year dummies included. Robust standard errors in parenthesis. * p<0.1, ** p<0.05, ***p<0.01.

Figure C1: Reduction in quantity discount for energy prices with respect to 1997



Results are based on estimates of equation 8. N=93,199.

Figure D1: Regression discontinuity design around the threshold for the exemption from the CSPE



The shaded area represents the 95 percent confidence interval of the estimate.

Table E1: Energy intensity of 2-digit sectors based on the average ratio between energy expenditure and wages paid

	High energy intensity
13	Manufacture of textiles
16	Manufacture of wood and of products of wood and cork
17	Manufacture of paper and paper products
18	Manufacture of coke and refined petroleum products
20	Manufacture of chemicals and chemical products
22	Manufacture of rubber and plastic products
23	Manufacture of other non-metallic mineral products
24	Manufacture of basic metals
	Low energy intensity
14	Manufacture of wearing apparel
15	Manufacture of leather and related products
21	Manufacture of basic pharmaceutical products
25	Manufacture of fabricated metal products
26	Manufacture of computer, electronic and optical products
27	Manufacture of electrical equipment
28	Manufacture of machinery and equipment n.e.c.
29	Manufacture of motor vehicles, trailers and semi-trailers
30	Manufacture of other transport equipment
31	Manufacture of furniture
32	Other manufacturing
33	Repair and installation of machinery and equipment

Table E2: Trade intensity of 3-digit sectors based on EU ETS criterion for exemption from auctioning

	High trade intensity
13.1	Preparation and spinning of textile fibres
13.2	Weaving of textiles
13.9	Manufacture of other textiles
14.1	Manufacture of wearing apparel, except fur apparel
14.3	Manufacture of knitted and crocheted apparel
15.1	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery and harness; dressing and dyeing of fur
20.1	Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms
20.2	Manufacture of pesticides and other agrochemical products
20.5	Manufacture of other chemical products
20.6	Manufacture of man-made fibres
21.1	Manufacture of basic pharmaceutical products
21.2	Manufacture of pharmaceutical preparations
22.1	Manufacture of rubber products
23.2	Manufacture of refractory products
23.4	Manufacture of other porcelain and ceramic products
24.2	Manufacture of tubes, pipes, hollow profiles and related fittings, of steel
24.4	Manufacture of basic precious and other non-ferrous metals
25.4	Manufacture of weapons and ammunition
25.7	Manufacture of cutlery, tools and general hardware
26.1	Manufacture of electronic components and boards
26.2	Manufacture of computers and peripheral equipment
26.3	Manufacture of communication equipment
27.1	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus
27.3	Manufacture of wiring and wiring devices
27.4	Manufacture of electric lighting equipment
27.5	Manufacture of domestic appliances
27.9	Manufacture of other electrical equipment
28.1	Manufacture of general-purpose machinery
28.2	Manufacture of other general-purpose machinery
28.3	Manufacture of agricultural and forestry machinery
28.4	Manufacture of metal forming machinery and machine tools
28.9	Manufacture of other special-purpose machinery
29.1	Manufacture of motor vehicles
30.1	Building of ships and boats
30.3	Manufacture of air and spacecraft and related machinery
30.9	Manufacture of transport equipment n.e.c.
32.2	Manufacture of musical instruments
32.3	Manufacture of sports goods
32.5	Manufacture of medical and dental instruments and supplies
	Low trade intensity
13.3	Finishing of textiles
14.2	Manufacture of articles of fur
15.2	Manufacture of footwear
16.1	Sawmilling and planing of wood
16.2	Manufacture of products of wood, cork, straw and plaiting materials
17.1	Manufacture of pulp, paper and paperboard
17.2	Manufacture of articles of paper and paperboard
18.1	Printing and service activities related to printing
18.2	Reproduction of recorded media
20.3	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
20.4	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
22.2	Manufacture of plastic products
23.1	Manufacture of glass and glass products
23.3	Manufacture of clay building materials
23.5	Manufacture of cement, lime and plaster
23.6	Manufacture of articles of concrete, cement and plaster
23.7	Cutting, shaping and finishing of stone
23.9	Manufacture of abrasive products and non-metallic mineral products n.e.c.
24.1	Manufacture of basic iron and steel and of ferro-alloys
24.3	Manufacture of other products of first processing of steel
24.5	Casting of metals
25.1	Manufacture of structural metal products
25.2	Manufacture of tanks, reservoirs and containers of metal
25.3	Manufacture of steam generators, except central heating hot water boilers
25.5	Forging, pressing, stamping and roll-forming of metal; powder metallurgy
25.6	Treatment and coating of metals; machining
25.9	Manufacture of other fabricated metal products
26.5	Manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks
26.6	Manufacture of irradiation, electromedical and electrotherapeutic equipment
26.7	Manufacture of optical instruments and photographic equipment
26.8	Manufacture of magnetic and optical media
27.2	Manufacture of batteries and accumulators
29.2	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
29.3	Manufacture of parts and accessories for motor vehicles
30.2	Manufacture of railway locomotives and rolling stock
30.4	Manufacture of military fighting vehicles
31.0	Manufacture of furniture
32.1	Manufacture of jewellery, bijouterie and related articles
32.4	Manufacture of games and toys
32.9	Manufacturing n.e.c.
33.1	Repair of fabricated metal products, machinery and equipment
33.2	Installation of industrial machinery and equipment

Table F1: Results conditional on firm's turnover

	log(energy cons)		log(CO2)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-1.202***	-0.607***	-1.726***	-1.119***
	(0.0308)	(0.0782)	(0.0552)	(0.118)
log(turnover - firm)	0.190***	0.203***	0.165***	0.176***
	(0.0123)	(0.0110)	(0.0161)	(0.0136)
F excl IV first stage		1370.5		1132.5
N	60600	60600	53978	53978
	log(empl)		log(average wage per empl)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-0.0444***	-0.164***	-0.00259	-0.0458***
	(0.0143)	(0.0533)	(0.00397)	(0.0174)
log(turnover - firm)	0.340***	0.338***	0.00787	0.00694
	(0.0169)	(0.0150)	(0.00545)	(0.00507)
F excl IV first stage		1370.5		1409.6
N	60600	60600	58806	58806

Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional control variables: year-sector (2-digit NACE rev 2), year-region (NUTS2) dummies, year-ETS dummies, year-peak (>Q3) dummies, year-size (initial size classes) dummies. Sample: establishment that are observed in EACEI for at least two years and observations three years or more after the first year in EACEI (used to build the initial energy mix for the IV). Excluded IV: log of national energy prices (by source) weighted with initial energy mix of the plant.

Table F2: Results using an alternative IV based on industry/decile of energy consumption energy mix

	log(energy cons)	log(CO2)	log(empl)	log(average wage per empl)
log(energy price)	-0.582***	-0.813***	-0.194**	-0.0320
	(0.0940)	(0.151)	(0.0753)	(0.0221)
F excl IV first stage	988.3	820.8	988.3	959.8
N	61153	54437	61153	59076

Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional control variables: year-sector (2-digit NACE rev 2), year-region (NUTS2) dummies, year-ETS dummies, year-peak (>Q3) dummies, year-size (initial size classes) dummies. Sample: establishment that are observed in EACEI for at least two years and observations three years or more after the first year in EACEI. Excluded IV: log of national energy prices (by source) weighted with average 1997-1999 energy mix of the sector/decile of energy consumption cell.

Table F3: Establishment-level results on the sample

	log(energy cons)		log(CO2)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-1.264***	-0.674***	-1.836***	-0.955***
	(0.0398)	(0.101)	(0.0771)	(0.161)
F excl IV first stage		856.9		684.5
N	33165	33165	28888	28888
	log(empl)		log(average wage per empl)	
	FE	FE-IV	FE	FE-IV
log(energy price)	-0.0861***	-0.315***	-0.00726	-0.0567**
	(0.0190)	(0.0791)	(0.00525)	(0.0228)
F excl IV first stage		856.9		832.1
N	33165	33165	32164	32164

Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Additional control variables: year-sector (2-digit NACE rev 2), year-region (NUTS2) dummies, year-ETS dummies, year-peak (>Q3) dummies, year-size (initial size classes) dummies. Sample: establishment that are observed in EACEI for at least two years and observations three years or more after the first year in EACEI (used to build the initial energy mix for the IV). Excluded IV: log of national energy prices (by source) weighted with initial energy mix of the plant.