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Sustainable Technologies Adoption and Energy Prices: the Drivers of Investment in the Green Transition

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Sustainable Technologies Adoption and Energy Prices: the Drivers of Investment in the Green Transition

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Abstract

Estimating the impact of energy prices on environmental investment is decisive for policy makers since this constitutes a possible incentive for the adoption of new, energy-saving and less polluting technologies. However, finding a positive relationship between the two is not easy given that this impact is clearly heterogeneous. Using data from French manufacturing industry between 2017 and 2020, this paper studies this impact by considering **interactions** of energy price with other intrinsic characteristics of firms and plants as a cause of this heterogeneity. This analysis is extended to evaluate the **inconsistency** of results between both levels. A possible explanation may be due to possible **budget restrictions**, which cause an increase in investment due to increases in the price of energy, not necessarily at the aggregate level of the firm but at the plant level, in those where its level of consumption is such that greater investment represents better efficiency of energy consumption.

Keywords: Energy price, Green Investment, Energy saving technologies, Interaction effects, Budget Constraint

JEL Classification: Q41, Q55, L60.

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1 Introduction

Under the current climate crisis and in search of the long-awaited ecological transition, Environmental Investment (EI) is becoming a topic of public discussion given the virtuous circles it can incite within a society. It becomes an asset that would allow us to face future crises due to its impact by allocating resources in critical areas such as clean technologies, waste management and pollution control especially when this represents energy efficiency improvements. In the long term, that means the possibility of stimulating research and entrepreneurship, creating jobs and promoting a green economic growth.

But EI, like other economic value, is subject to the vagaries of the market, especially when a manager must make a decision considering the advantages and disadvantages of this particular type of investment over a given time horizon. A manager must respond quickly to a crisis and EI can be both an essential strategy to respond to a demand shock, or a budget constraint where the short term outweighs the long term. Two events of the last five years seem to confirm the validity of this proposition: **(1)** the COVID-19 pandemic and **(2)** the Russian invasion of Ukraine.

The pandemic produces tighter financial constraints and adverse economic conditions that were detrimental to firms' environmental performance, including EI (Guérin and Suntheim, 2021). The European Union (EU) faced an economic downturn close to 10%. The energy sector witnessed a fall in energy demand and supply, and lower levels of CO2 emissions and air pollution. This led to a lower level of investment in renewable energy, a reduction close to one-third in 2020, compared to 2019 (IEA, 2020).

On the other hand, the war in Ukraine increased energy costs due to the reduced availability of natural gas in the EU. This scenario was conducive to an increase in energy investment of about 8% in 2022, but almost half of the increase in capital spending was linked to higher energy costs (IEA, 2022). Two main factors were important for this behavior: the interest in increasing the energy generation capacity of renewable sources and, especially, energy savings by companies [1]. Although this must be considered carefully when some organizations point out the impact that price increases can have on the energy bill, worsening "the investment environment for low-carbon energy sources and technologies which are vital for the transition to cleaner and more resilient energy systems" (Fernandez-Álvarez and Molnar, 2021).

These facts show the importance of market pressure as a driver of firms' investment decisions among other factors [2]. For instance, with respect to the European case in 2019, more than 40% of EU firms took measures to improve energy efficiency, when almost a third of them reported energy prices as a major obstacle to invest (EIB, 2020). But energy prices become an incentive as well, since it promotes precisely GI through energy-saving technologies or less polluting production chains. This is where the main question that this paper seeks to address arises: **how energy prices impact companies' EI decisions**. The trade-off between incentives and costs is interesting

[1]In fact, energy saving was a widely publicized request by the President of the European Commission Ursula von der Leyen. In her terms, talking about the measures to face the energy crisis: "the first one is smart savings of electricity ... so whatever we do, one thing is for sure: we have to save electricity, but we have to save it in a smart way" (EC, 2022).

[2]Some studies indicate that the share of firms investing in energy efficiency appears to be positively associated with the energy intensity and size of firms (EIB, 2020).

for policy makers, specially when the role of energy cost in investment decisions differs across jurisdictions and sectors [3].

This paper belongs to the field of the literature that assesses the microeconomic impact of environmental regulation. The work of Dinkelman (2011), Banerjee et al. (2012), and Alby et al. (2013) can be considered seminal contributions to this field by studying the impact of the public infrastructure (i.e. energy grid or public transportation) on the quantity and quality of inputs offered and their impact on the economic and environmental performance of firms. However, contributions analyzing the real impact of energy prices become somewhat scarce as soon as it is considered that this impact may be indirect or direct. The papers of the first group refer to the consequences of power outages and carbon tax assuming changes on prices as an external shock or as a regulatory measure. The papers of Martin et al. (2014), Allcott et al. (2016) and Ganapati et al. (2020) are highlighted here. The second group studies the direct impact of energy prices or market pressures on various business outcomes, as Abeberese (2017), Brucal and Dechezleprêtre (2021) and Calì et al. (2023) do. Finally, these three groups tangentially explain the fourth group of interest, the literature related to the factors that determine the adoption of sustainable technologies. The efforts made by Popp (2002) and Aghion et al. (2016) in describing possible transmission channels that explain why a company adopts one or another technology are important.

This paper points in that direction, by recognizing energy prices as an decisive determinant to make a decision about investment. To achieve this, this document will study the impact of energy prices on the EI decision taken by French companies particularly on Green Investment (GI) and the amount allocated for Research and Development (R&D). This document goes one step further by recognizing that this response can be differentiated depending on the intrinsic characteristics of the companies (size, energy or capital intensity), and a possible inconsistent effect between the responses given by plants and firms since the observational unit is completely different. This paper focuses on France, a signatory of the Paris Agreement in 2016 and of the European Green Deal in 2018, that thanks to its progress in the energy transition process, has become in the third largest producer of renewable energy in Europe and the first exporter of electricity in the world (Invest in France, 2023).

The use of three rich databases provided by the Institut national de la statistique et des études économiques (INSEE) gives an ideal scenario to not only study the impact of the energy market on investment, but also the differentiated short- term impact between firm and plant during the period from 2017 to 2020. The strategy is straightforward by compiling two databases, one at the plant level and one at the firm level, where each plant belongs to a firm in the opposite database. This makes it possible to assume different levels of interdependence among observational units, a structure that is ideal to improve the causal inference between energy prices, GI and R&D. The idea is quite clear: possible empirical specifications to study short run responses to exogenous changes on energy prices must include the idea that some plants belong to a specific firm.

The methodology was designed precisely to investigate the interaction and consistency of the energy price effect. For the first point, the interaction effects, the identification strategy relies on the use of a fixed energy price index as instrument variable for

[3] In France, almost 35% of firms invest in energy efficiency measures, while 15% of them say that energy costs is the major obstacle to investment (EIB, 2020).

the average energy cost initially for the firm level, approach used by Linn (2008), Sato et al. (2019) and Dussaux (2020). The specification uses three different aggregations of EI: GI (Clean Technologies and End-of-Pipe), R&D, and the sum of both, as continuous and binary outcome variables, following Hammar and Åsa Löfgren (2010), Triguero et al. (2013) and Triguero et al. (2015). The specification includes the lag of energy price and a set of control variables focused on the characteristics of the observational unit and environmental certifications. For the second analysis respect to the firm-plant consistency, we repeat exactly the same specifications at the plant level, but adding an additional one in which it is allowed to include the fact that a firm may contain several plants, a behavior that allows estimating panel data models with mixed effects.

This paper finds that energy prices, even if there is or is not a direct impact, interact with other characteristics of the companies to produce differentiated effects across the observational units, particularly when that firm or plant is energy or capital intensive. Regarding consistency, and particularly the direct effect of energy prices, there is evidence showing a non-significant impact at the firm level, but a positive and significant impact at the plant level. This effect can be due to economic and managerial differences between firms and companies: while the plant is the economic unit where the production process takes place, it is in the firm where management and financial decisions are made.

This difference can be understood as a consequence of possible budget constraints. It refers to the limitations and boundaries on the financial resources available for the firm to allocate towards various activities, investments, and expenses. This represents the maximum amount that a firm can spend given its available income, financial resources, and financial objectives. The budget constraint arises from the need to make decisions about how to allocate limited resources efficiently among different options, i.e., plants. Several authors have studied the impact of this restriction on the behavior of companies in different financial and sustainability variables, but the seminal contribution of Kornai (1979) is undoubtedly fundamental to understanding the phenomenon [4]. In our case, faced with a possible increase in the energy price, the firm must make a decision as to which plant to allocate a higher level of investment, a process that should be considered in terms of costs and energy efficiency. Thus, a given amount of investment must be distributed to only a particular set of plants, so that the effect between plants may be positive but not the aggregate effect between firms.

In order to study this hypothesis, auxiliary regressions were performed by differentiating between single-plant firms and multi-plant firms, since the last group face the budget restrictions. In addition, we include a ranking approach, by considering the position of a given plant in its firm in terms of the energy consumption intensity. This allows to quantify the sensitivity of the difference in investment between the most and least intensive plant to a change in the price of energy. The evidence indicates that firms do indeed face a budget constraint, so that changes in energy price will not alter the aggregate level of investment, but will impact the investment allocated to the most intensive plants in terms of energy consumption.

This paper contributes to the literature explaining the impact of energy prices on en-

[4] This type of literature is characterized by categorizing different firm incentives, differentiating between a "Hard Budget Constraint" that involves sustaining losses with profits, and a "Soft Budget Constraint" where losses are borne by an external agent, e.g., the state. This terminology was very popular during the transition of the former Soviet bloc countries to market economies.

vironmental investment by providing evidence of possible interaction effects instead of a unique direct direction. This remark was something discussed by Fu et al. (2018) advocating for a more integrated conceptual model for sustainable technology adoption that includes the interrelationships between factors. In addition, studying the consistency of results between plants and firms becomes a key contribution since it can reassess the validity of previous academic contributions, particularly for the French case. Dussaux (2020) and Marin and Vona (2021) are quite advanced in this methodological approach, although they use a much less general definition of firm than the one used in this paper. Finally, this paper improves our understanding about the impact of energy prices on different investment aggregations, i.e., GI and R&D, by seeing that although the signs of the effects are the same, they do not follow the same pattern and the sensitivity and significance are not equal. This becomes a gateway to investigate the impact of market pressure on the adoption of various sustainable technologies which may be motivated by totally different incentives, something that Frondel et al. (2007) already discuss. More research should be directed in that direction.

The document is organized as follows. Relevant literature and the first hypothesis are presented in the following section. The presentation of databases, sources, aggregation and initial statistics is discussed in the third section. The fourth section studies the problem of interaction and consistency in the effect of energy price on investment by explaining the methodology, the estimations for the firm and plant level, and some robustness checks. The idea about the budget constraint hypothesis is introduced in the fifth section by analyzing the regressions between single-plant and multi-plant firms and the ranking approach. This paper finishes with some concluding remarks and discussions about further research.

2 Literature Revision

The literature related with this topic is fairly recent, no more than thirty years, and is characterized by being quite general in analyzing the impacts within the energy market on different links of the economy. Initially, the academic contributions were based on quantifying the impact of public infrastructure as a way to explain the importance of those services as inputs *sine qua non* the production process is impossible to carry out. As example, Alby et al. (2013) study the behavior of companies where the energy infrastructure is deficient and they decide to invest in self-generators, a scenario where the second-best solution is preferred despite the presence of the first. In the opposite side, Acar and Berk (2022) show that transmission and distribution losses negatively affect both manufacturing production and value-added in a sample that includes OECD countries. But sometimes those studies are focused on the impact of external shocks in the intrinsic energy generation process on the firm performance, when it is not necessary a direct change in energy prices. Two particular cases are emphasized here: shortages and carbon taxes. Although these are specific phenomena, these are important contributions in explaining the response of companies to unforeseen and short-term events without any adaptation involved. With respect to carbon taxes, Martin et al. (2014) conclude that this type of tribute has a strong negative impact on energy intensity and electricity use, while the impact is not significant on employment, revenue or plant exit. While Ganapati et al. (2020), studying the energy cost pass-through, estimate that 70 percent of energy price-driven changes in input costs get passed through to consumers in the short to medium run. With respect to shortages, Grainger and Zhang (2017) show that a 10 percent increase in the duration of outages on average leads to a 0.14 percent decrease in a firm's total revenue and value added, but more than that, there is a differentiated impact when the industries that are most energy intensive are affected more by shortages. Fisher-Vanden et al. (2015) follow the same trend, finding that firms re-optimize among inputs by substituting materials for energy in response to energy scarcity. In that way, the companies can avoid productivity losses, but by increasing production costs.

The relevance of these contributions lies in the similarity of shortages and carbon taxes to direct changes in the price of energy. As Allcott et al. (2016) mention, a great part of the literature focus on the effect of shortages (but not in price shocks) and how it modifies business decisions, for instance, buying a generator. The authors explain that power outages act exactly like a time-varying tax on electricity, or a price that tends to infinity. The electricity price increase causes plants to reduce electricity consumption, which reduces the marginal revenue products of materials and labor.

For our particular case regarding energy prices, usually this term is studied jointly with the interaction of other factors, i.e., energy demand. This is called in the literature as "market pressure", and its importance is analyzed through the impact on several outcome variables, but under quite general results, as in the case of investment. Linn (2008) establishes that an increase in energy price reduces the relative energy intensity due to the adoption of energy-saving technologies. But Sadath and Acharya (2015) found that energy price rises have negative effect on the investment of firms in the manufacturing sector, possibly due to the cautious approach to investment adopted by Indian companies, aspect that Sahu and Narayanan (2014) disagree with by finding that the level of investment depends more on the level of energy intensity than on a direct effect of energy price. Dlugosch and Kozluk (2017) went a step further by determining that higher energy price is associated with a decrease in total investment, although it can increase in the most energy intensive sectors in a sample that includes OECD countries. Rentschler and Kornejew (2017) consider that Indonesian firms adapt to higher energy prices by adjusting their energy mix or by increasing energy efficiency, something that Abeberese (2017) take up to conclude that firms switch to less energy intensive production processes, reduce their machine intensity. More recent contributions include Brucal and Dechezleprêtre (2021), which show that energy price changes have no significant influence on net job creation possibly explained by the idea that jobs are not lost but reallocated from energy-intensive to energy-efficient firms. Çürük and Rozendaal (2022) find no evidence that energy prices affect industry concentration, markups or the value added to output ratio, an important implication about the distributive consequences of environmental policy. Wolverton et al. (2022) study again the impact of higher energy prices using American data, and finding that plant electricity usage declines with an small impact on output, employment and hours worked. Finally, Calì et al. (2023) suggest that the size and direction of the impact of growing energy prices depends on firms' energy intensity, among other characteristics. Again, the idea that the impact of price is not direct or one-way, but differentiated.

The academic work related with France deserves a special mention, since those contributions are the closest approaches to this paper, always with the objective of analysing a higher energy price on firms' performance. Those are Dussaux (2020) and

Marin and Vona (2021) [5] , which study energy price effects on several environmental and economic outcomes using a shift-share instrument inspired by Sato et al. (2019). They used the same data sources as those employed in this paper, and a similar firm/plant approximation, where plant is defined as an *établissement*, and firm as an *unité légale* according to the French law [6].

Dussaux (2020) finds a negative impact of energy prices on total investment at the **firm level**, but non-significant, that changes according to the size of the firm. In addition, he studies the effect on technology development and adoption, to conclude that a 10% increase in the energy price leads to an increase in the stock of patents of 6.3% for large firms and a decrease of 3.5% for small and medium ones. As robust check, the author uses the investment amount of pollution abatement in several types as outcome variable, and the energy price as the main independent variable. He finds evidence that an increase in the energy price is positively and significantly associated with investment in air, water and waste pollution control investment only for the **plant level**. Then, if energy becomes more expensive, there are incentives to invest in more energy efficient abatement technologies to keep a given amount of pollution. Now, the different analyses at the firm and plant level are due to data processing, since disaggregating each type of investment implies losing information from some plants, so that in the aggregate the information is not relevant for the firm level. The story is not completely different with Marin and Vona (2021). The authors find that increases in energy prices reduce consumption and CO2 emissions, with modest reductions on employment and productivity, and no effects on wages. This is a trend that continues at both the plant and firm level, although it does not refer to any analysis of investment, and continues with the same approach of the firm as *unité légale*.

The latter contributions advanced by studying a possible differentiated firm/plant effect on several performance variables, such as EI among them. But it also allows to reconsider new approaches to the definitions of both firm and investment. Their discussion would lead to new methodologies, as well as a re-evaluation of previous results. Regarding the first point, about the definition of the firm, what is an *entreprise* must be should be taken up again. Following the French law n° 2008-776 and the INSEE (2019), an *entreprise* is therefore either an independent *unité légale* [7], being an individual entrepreneur or a company with its own production process, or an economically relevant grouping of *unité légales* belonging to the same society, operating on the market and combining all production factors. Using *entreprise* as definition of firm could be a better approximation since, in comparison with an unique *unité légale*, the first one considers the level of decision-making autonomy which is not a matter of being an *unité*

[5] Recent contributions include Marten (2022), which use plant level data to describe the impact of the Carbon Pricing Reform on French manufacturing. The author finds that a reform of this kind is not associated with a change in electricity use levels, but with a drop in fossil fuel use.

[6] According to the French law n° 2008-776 (Loi de modernisation de l'économie - LME), an *établissement* is a production unit geographically individualized and dependent on an *unité légale*. The *unité légale* is the legal unit that groups different *établissement*. While an *entreprise* is the smallest combination of *unité légale* that constitutes an organizational unit of production of goods and services enjoying a certain autonomy of decision (Fleckinger et al., 2023). This paper agrees on using *établissement* as an approximation of plant, but differs in defining a firm as an *unité légale*, as Dussaux (2020) and Marin and Vona (2021) do. Since managerial decisions are made at a higher level, this document takes a *entreprise* as a reference for a firm level.

[7] Identified by a SIREN number

légales or not, but whether they belong to the same business group. In other words, taking *unité légale* as a firm could lead to consider subsidiaries of groups, without a clear economic and management criteria. Taking *entreprise* is the approach used in this paper.

Respect to the definition of EI, it is relevant to consider the different definitions of it, since each of them can lead several implications in terms of the behavior of the firm. Sustainable process technologies, or EI for the purposes of this paper, are divided into End-of-Pipe technologies (EOP) and Clean Technologies (CT), according to the level of integration that they have in the production process (Fu et al., 2018). EOP add extra equipment to the plant without changing the scheme of the production process, e.g., scrubbers and filters which reduced pollution in the atmosphere. CT can reduce the level of pollution as well, not at the end of the process, but from the generation itself. This implies that CT modify the production process, e.g., thought new energy-saving technologies (Frondel et al., 2007). A third group that is not traditionally considered is investment in research and development (R&D), a component that can facilitate the implementation of EOP and CT. Note that the behavior of companies with respect to each of these types of investment does not necessarily depend on the same variables and the same magnitude. This is something discussed by Fu et al. (2018). For the particular case of Dussaux (2020), he uses investment classified as EOP in their different ways. This methodology could be reevaluated given that, by hypothesis, CT could be more sensitive to increases in energy prices than EOP, an aspect that could underestimate the effect found by the author, resulting in biased estimates.

Although some contributions have realized that inconsistency, as Theyel (2000) which found that firms with the highest adoption levels of environmental practices prefer CT than EOP. Or the seminal contribution of Popp (2002), that established a positive and significant relationship between energy prices and innovation by insisting that omitting the quality of knowledge affects the estimations (i.e. ignoring the type of investment). Hammar and Åsa Löfgren (2010) conclude that the probability of a firm investing in CT increases if the firm has R&D, but energy price is important for EOP, in an scenario where both have a high level of complementarity. By their side, Demirel and Kesidou (2011) consider that EOP and CT depend on the "equipment upgrade motives" with a view of improving efficiency, but environmental regulations are effective for EOP and R&D, a result that confirms Weng and Lin (2011) regarding ISO certifications. Bhupendra and Sangle (2015) add an additional factor to promote innovation: a top management with high risk-taking ability, with a sufficiently high level of risk to implement CT. Triguero et al. (2013) highlight the importance of the collaboration with research institutes, and the pressure from the demand to make possible eco-innovations, while their document of 2015 includes the size of the companies: cooperation is important for small firms, but not for mid-sized firms, an aspect that is replicated with subsidies an specially for CT. For them, the role of existing environmental regulation is a key factor since it helps to explain the adoption of CT for for medium firms. Finally, Aghion et al. (2016) found that firms innovate more in CT when there are high tax-inclusive fuel prices, although the path can change according to the characteristics and innovation history of the firm.

A final point to discuss is the validity of the results from economic theory, particularly the behavior that establishes a possible positive or negative relationship of energy prices with the level of investment, independent of its type. As explained above, empirical approaches can obtain different results and paths, but the literature pays attention to one in particular: the Porter Hypothesis. Initially discussed by Porter (1991) and Porter and van der Linde (1995), and reformulated by Jaffe and Palmer (1997), the idea behind that is quite easy to understand: environmental policies might instead raise the productivity of firms. That means that a market-based policy, as a carbon tax, could increase innovation in terms of energy-saving technologies, i.e., higher prices lead more investment and innovation. This positive relationship is one that is continuously found in the literature as we saw before. But why is this behavior widely accepted by different empirical approaches? The key is the reallocation of resources. According to the OECD (2021), "some firms might exit the market because they are unable to cope with the new regulation, new firms might enter with disruptive technologies, and production might be shifted away from less productive toward more productive firms". Indeed, this behavior can change among different levels of observational units. The OECD (2021) refers to the difference industry/firm, particularly the potential factor reallocation across firms within an industry, but this could be replicated at the firm vs plant level. This is important since the Porter Hypothesis validity, and thus the relationship between energy prices and investment, may depend on the level of dependency among the observations, an aspect that may explain the variety of results.

3 Data

3.1 Sources, definitions, and data aggregation

The data aggregation and the definition of variables result in two unbalanced panel data of almost 7800 firms and 12500 plants observed yearly from 2017 to 2020 [8]. Those are built from three different databases administrated by INSEE. The information about energy prices and energy consumption comes from EACEI (*Enquête sur les consommations d'énergie dans l'industrie*), which disaggregates the information respect to the source, mainly electricity and gas for this case. The information about investment comes from ANTIPOL (*Enquête sur les investissements dans l'industrie pour protéger l'environnement*), which contains the amount invested on EOP, CT and R&D. These databases contain the information in the plant level (*établissement*) [9], although it contains the information of which *unité légale* each *établissement* belongs to. In that case, it is necessary a bridge to aggregate the information at the firm level. This is done thanks to FARE (*Statistique structurelle annuelle d'entreprises*), which publishes the list of different *unité légale* and *entreprise* they belong to, in addition to some financial variables, as assets, debt or net sales for the different *entreprises*, i.e., at the firm level. The aggregation is straightforward since we have the different *unité légale* in both sides of the data: EACEI and ANTIPOL at the plant level, and FARE at the firm level. Having *unité légale* works as a link since it can give us the list of *établissement* with their *entreprises*, in better words, a complete categorization plant/firm. For the aggre-

[8]Although a part of the observations are lost since we use the first lag of energy price in the econometric estimations. That is because we only have one observation for some firms and plants

[9]EACEI contains all plants with more than 250 workers, and a sample of plants between 20 and 249 workers belonging to sectors considered as extractive and manufacturing industries. ANTIPOL includes all plants with more than 20 employees within the extractive, manufacturing and energy production industries.

gation, the variables are summed or including in a weighted average according to the nature of the variable. For instance, variables as consumption or number of workers are summed, but for prices a weighted average is necessary in terms of the consumption for a specific source.

We guarantee that the plants that are on one side are represented by firms on the other, although there may be a loss of information since it cannot be claimed that the information contained in the part of the firms is relevant. This is because EACEI and ANTIPOL might not contain all the plants of a particular firm, so hardly information from a single plant can be relevant to a multi-plant firm. To overcome this, a variable in common between the two databases is used: the number of workers, a strategy inspired by Dussaux (2020). The rule of choice is to sum the number of workers between plants and compare it with the number recorded at the firm level in FARE. If the number of workers among the plants recorded is at least 90% of those recorded at the firm level, the observation for that firm is considered relevant.

It is important to mention that the firm database only include observational units classified as manufacturing industry. The plants that belong to that firm could be classified as any type of industry. That is why we could make statistics by considering the economic sector at the plant level [10]. In addition, We deflate the databases using the standard Consumer Price Index published by INSEE, in the way that all the monetary variables registered here are in euros (or thousands of euros) of 2020.

Now, to analyze the impact of energy prices on EI, it is necessary to define the two main variables presented here: energy price and investment. The nature of those variables does not change across database and are result of the original surveys (for the plant level) or the aggregation discussed before (for the firm level).

- The energy price is defined as the weighted average of energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh). The weights are the ratio between the quantity purchased for that specific source and the total. We only include two sources of energy since those explain between 90% and 95% of the total energy consumption across firms, although adding more is possible by changing the measure unit.

- The outcome variable, i.e., investment, is defined in three different ways. The first variable is called Green Investment (GI) and is the sum of what the literature calls EOP and CT investment [11]. The second one is Research and Development, following the same definition of R&D given before. And the last one is Total Investment (TOTI), which is the sum of GI and R&D. The advantage of using ANTIPOL as the main database of investment is that we can consider the realization of any kind of investment, and not only the monetary amount. This last variable configuration is defined in this document by adding a D in the name of the variable, which shows its nature as a qualitative variable.

Regarding the control variables, there are some that are shared for both firm and

[10] We mean for sector the two-digit code of the French product and activity nomenclatures (NAF) which is now as "division" by INSEE

[11] Note that using only one type of investment entails losing observations within the sample since there are firms and plants that only invest in a specific category. Both types must be considered in order to generalize any results, even if the impact on the production process is different.

plant database. Those are the net energy consumption (by ignoring possible self-production), the number of workers and the energy use per worker, and a group of qualitative variables regarding environmental certifications. At the plant level, they refer to whether the plant complies with the certification, while for the firm level if at least one plant complies with it. These variables are defined as:

- **ISO14:** the certification ISO 14001 which establish some criteria for environmental management systems.
- **ISO50:** the certification ISO 50001 concerning energy management system.
- **ICPE:** French regulation, it refers to whether the firm or plant has facilities that may have impacts or hazards on the environment.

Given that we have access to more information in the firm database by using FARE, we can add some control variables in the firm level that are impossible to include in the plant level. Those are the number of plants, the tangible investment per worker and a VETUS index [12], defined as a proxy of the age of the machineries where the variable is equal to 1 if the machines are "new" and close to 0 if they are "old". The summary statistics for the firm level is presented in table 11, and the plant level in 13.

3.2 Sample behavior and correlations

According to figure 5 and 10, energy price does not vary greatly across years since the period of observation could be considered small, although it varies quite significantly with respect to the level of consumption by following figures 6 and 11. This variation can be seen across the different sectors at the plant level by checking figures 14 and 15. This behavior is consistent with the idea that higher level of consumption represents an open door to negotiate contracts that represents a lower energy price for the purchasing. Dussaux (2020) and Marin and Vona (2021) documented about this trend in their papers.

Regarding investment, figure 7 shows that it varies significantly across years, despite the weight of each kind of investment in the total is stable with CT and EOP explaining both 45% and R&D explaining 10% of the total level of investment. As energy price, this behavior varies according to the sector at the plant level as figure 12 shows. In line with expectations, we found that the most energy intensive sector present more levels of investment compared to the others. We are talking about services associated to extractive industries, and with a lower magnitude the chemical and metallurgic industries, sectors that could require a higher level of investment to promote energy-saving technologies or pollution abatement.

The sample behavior regarding the control variables is quite important as well since it allows us to generalize conclusions for a population. We use histograms in figures 8 and 13 to establish the relevance of the sample, particularly in term of the firm/plant size. Regarding the firm level, the database has an over-representation of micro and small and medium-sized firms, seen from the number of workers, as well as the number

[12]It is a French acronym referring to the age of the machinery. It is calculated through the ratio between fixed assets without depreciation and fixed assets plus depreciation. When the value is close to 1, it means that there is no depreciation so the machines are new.

of plants where single-plant firms predominate. This remark can be valid for the plant level database. This trend is due to the fact that the universe of plants is not exactly the same between EACEI and ANTIPOL, so merging the two surveys means sacrificing the level of representativeness under INSEE standards to obtain conclusions on the universe of establishments in France. This should be considered for future conclusions on the quality of the database.

The estimated Pearson correlations between the investment and control variables (table 12 and 14) deserve a special comment, although none of them are above 0.5. We refer to the signs as these may provide the first hypotheses regarding the effect of energy prices and control variables on investment. The correlations, like our expectations, point to a positive relationship between investment with net energy consumption, consumption and investment per worker. This means that with higher energy and capital intensity, there are indications of a higher level of investment. Regarding the negative correlations, for the VETUS index [13] and the number of plants, it can be explained by the fact that older machinery would require a higher level of investment, while a higher number of plants would require the company to disperse investment (by possibly nullifying a possible aggregate effect on the firm's total). The correlation regarding the energy price is surprising since it is negative, thus invalidating the possible explanation provided by Porter and leading to the conclusion that price increases are not necessarily an incentive to invest more. This incongruence between the expectation of Porter's hypothesis and the correlation supports the purpose of this paper, since to validate the negative direction of the correlation it is necessary to isolate the other effects, and in a way to find the true direct effect of price on investment.

3.3 Hypothesis: Porter or a matter of intensities

Discussing the hypotheses about the effect of energy price on investment implies understanding the nature of Porter's idea insofar as it represents a possible direct effect. If there is a direct effect, it is possible that there are other factors that prevent the price effect from being isolated, and even more so, they also become investment drivers. To explain this in better words, it is interesting to analize energy price as an "external" variable, and why it is associated with an endogeneity problem. But before that, recognize that a investment driver can be both an external shock or a characteristic of the firm/plant itself. Energy price contains the external component (the price of different energy sources, i.e. electricity or natural gas) and an internal component (in terms of the consumption decision). Clearly this codifies a simultaneity problem, where both variables are defined at the same time, and furthermore, that a possible price impact will also depend on the level of related consumption. That idea introduces the fact that the impact of energy price can be differentiated, and it is not only a matter of a homogeneous direct impact across firms and plants.

Take again the Porter hypothesis, a positive effect of prices on investment, and combine it with the possibility that the impact of price depends on other variables as energy consumption. On the first hand, higher energy prices lead an increase of investment since it could reduce the energy consumption by supporting energy-saving

[13] As a proxy of the age of the machinery, where 0 equals old machines while 1 is new ones. This index will be explained with more details below

technologies, and in that way, the energy bill. But realize that this shock also has a temporal window, since it could be positive only when the time horizon is long enough to adapt the production process to these type of market shocks. Thus a negative impact is not only possible, but viable if conditions allow it. A possible interpretation for this is that a higher energy price could sacrifice investment to keep stable the energy consumption and not to affect the production process. As result, the Porter's hypothesis is violated when considering that energy consumption determines the impact of the energy price. This leads to the inclusion of new dimensions in which the energy price interacts to generate changes on investment. Those dimensions must consider other factors that affect investment depending on the own characteristics of firms and plants, a strategy that becomes imperative to study the direct impact of price.

We call the different dimensions considered here "interactions", since they work as a interaction variable in a standard econometric model taking always energy price as main explanatory variable and with which all the others interact. Those interactions are:

- **Resource Intensity Effect (RIE):** this is the interaction with the Net Consumption per Worker. Initially, a joint term between total consumption and energy price is a proxy for energy bill. This is important since it gives a new hypothesis: a higher energy bill could increase the green investment, precisely to reduce the impact of a higher energy price. this could be interpreted more as an economic efficiency argument to increase investment over technological efficiency where only energy consumption is considered without interaction with the price. But the energy bill, although is a proxy for absolute energy intensity, it is not in a relative level. This is why using consumption per worker is more reliable to detect a possible effect since this catches both dimensions: the energy bill and the high energy consumption with a stable number of workers, i.e., the relative energy intensity [14]. Under our expectations, we expect that a higher energy price leads to a higher investment when the level of consumption or energy intensity is high. Again, this is a response to facilitate energy-saving technologies by being the most efficient decision in economic and technological terms.

- **Capital Intensity Effect (CAI):** this is the interaction with the Tangible Investment per Worker using it as a proxy of capital intensity. Initially, we expect that a higher amount of capital requires a larger amount of investment to keep it, and an even more level on investment if the manager wants to promote energy-saving technologies by facing a higher energy price.

- **Technological Capability Effect (TEC):** this is the interaction with the VETUS index. When the index is close to 0, the firm could have old machines that do require many investment needs. When the price increases, but the machines are new, the needs of investment are reduced since there is no more space for changes. When the energy price increases and the machines are old, there is a

[14]Indeed, there is another problem by adding total consumption in the empirical specification since putting it together with energy price will create a problem of simultaneity. Of course, this implies that the price of energy is an endogenous variable, a problem that must be solved to improve the causal evaluation of the variable.

chance, to replace those machines with the best technology possible through increasing investment, acquiring the best energy-saving technologies. This means a negative impact of the interaction on investment.

- **Size Effect (SIE):** this is the interaction with the size of the firm. Preliminary, one can think about adding qualitative variables according to the size of the company, but detecting a possible SIE could be complicated whether new include several of them. A possible solution is adding only one quantitative variable avoiding to lose information, for instance, the number of workers, which is the variable that will interact with energy price. Following our understanding, when a company is big enough, the needs to save energy are higher with an increase of energy price. In fact, this is a sign of the greater economic capacity of large firms over small ones that may have restrictions in terms of budget or credit.

To summarize, the inclusion of these interactions terms would allow to detect the direct impact of price since they separate the direct effect from the interaction effect. This strategy manages to evaluate Porter's hypothesis ignoring possible cofounders that generate the differential impact of the price. Now, as we discussed in previous sections, given the different nature of the databases at the firm and plant level, it is only possible to study RIE and SIE for the plant analysis, although this is not an obstacle to evaluate the direct impact of price at the plant level with the only difference that we have less empirical specifications.

4 Interaction and Consistency: the effect of energy price on investment

4.1 Methodology

4.1.1 Empirical approach

To recapitulate, we want to estimate the short-term effect of a change in energy prices on the EI made by firms and plants. To achieve this, the following linear model is estimated for both firm and plant level:

$$I_{it} = \beta_0 + \beta_1 P_{it-1} + \beta_2 T_{it} + \beta_3 P_{it-1} T_{it} + \beta_4 X_{it} + \lambda_f + \lambda_s + \lambda_y + \epsilon_{it} \tag{1}$$

Where I is the investment variable for the unit i at time t, such as GI, R&D and TOTI [15]. P is the log of the average energy cost under the definition given before. T is the variable involved in the interaction, that for our case it can be the Energy Use per worker, Tangible Investment per Worker, the VETUS index or the number of workers. The interaction can be seen in β_3, the same that we defined as RIE, CAI, TEC and SIE. X is a vector of controls that includes all the variables not involved in the interaction and the controls discussed in previous sections such as the environmental certifications or the number of plants for the firm case. Only one interaction is included to facilitate the interpretation of coefficients and the interactions. λ_f, λ_y are firm and year fixed effects,

[15] The realization of the investment is also include in the estimation by using binomial models, although those are included in the robust checks section

while λ_s is a sector fixed effect included only for the plant level analysis. As Dussaux (2020) says, the inclusion of fixed effects allows to control for time-invariant and firm-specific characteristics that may be correlated with energy price and the investment variables at the same time, but for our particular case, those can be correlated with other characteristics included in the group of control variables. Given this, adding those fixed effect terms to the estimation is optional [16] [17]. The only regressor that is lagged is the energy price to capture the fact that firms and plant need time to readapt to new conditions. All the quantitative variables are logged except the VETUS index. The estimation includes robust errors always at the firm level [18].

This estimation represents one step further from the specifications cited by Dussaux (2020) and Marin and Vona (2021), and indeed, this solves some of the problems found by Fu et al. (2018) regarding the possible differential effects. But some remarks must be made given that the interactions used here are between two continuous variables and not between one continuous and one categorical as the standard literature does. This is problematic since the coefficients cannot be read taking one category as reference. As Aiken and West (1991), and Jaccard and Turrisi (2003) mention, there is a possible solution by centralizing the variables involved (subtracting the sample average for each observation). With this new database, and taking 1 as reference, that means that β_0 is the effect when both energy price and the variable involved in the interaction are equal to the mean, and β_1, cited here as the direct effect of price, is the impact only when the variable involved in the interaction is equal to the mean, given the other causes constant. The same interpretation occurs with β_2. In better words, we isolate the direct effect of price by studying the scenario where all the other variables are equal to the sample mean.

4.1.2 Instrumental variable

The estimation of 1 uses two methodologies: the standard Least Square (OLS) and the Two Stage Least Square estimator (2SLS) given that the energy price as regressor could be endogenous. It is viable to say that energy price is correlated with unobserved factors that determines the amount of investment too. A second reason, more methodological, refers to the construction of the energy price since it includes the level of energy consumption. Investment and consumption are both decisions made by the firm or plant, something that configures a simultaneity concern. The instrument used to deal with this problem is inspired by Sato et al. (2019), an exogenous energy price index as explanatory variable for the energy cost. This variable takes as basis the average national price in Euro per MWh without taxes applicable for the first semester of each year for medium size consumers, and a weight defined as the ratio between the consumption of the fuel (electricity and natural gas) and the total energy consumption in the first year of the sample.

Now, the idea of using instrumental variables is to include only the exogenous be-

[16] In fact, during the estimation we did not find statistical evidence to include firm or plant fixed effects, although the different estimation combinations are shown in the document as a matter of transparency.

[17] For the case of a year fixed effect, it could be debatable since the COVID-19 pandemic happened during our period of analysis, an important turning point even if the time horizon is only of four years.

[18] Robust errors at the plant level were impossible to include given computational limitations.

havior of the endogenous variable. Then, using an instrument with the consumption basket for the first year of the sample may be problematic if that year is included in the final regression. This is solved by adding the lag of energy price since we would never use information from the first year for which we have data for a specific plant or firm. Regarding the relevance of the instrument, the first stage regressions show the pertinence of using this external index as instrument for our estimation. Those tables can be found in tables 15 and 16 posted in the appendix [19].

4.2 The firm level: interactions effects

Tables 1 and 2 show the estimated effect of energy price on the environmental decision at the firm level. The main finding is the positive impact of energy price following the Porter's hypothesis as the direct effect, but a coefficient that is not significant. In that case, the interpretation and the importance of energy price relay on the interaction terms. It seems that the higher the energy intensity (REI), the capital intensity (CAI) and the lower the technological capability (TEC), the more decreasing the impact of price on the level of investment. This is important since we can detect a possible interaction impact instead of a direct impact as the standard literature does. For this case, the size impact does not seem relevant.

The interpretation of this behavior is quite straightforward. Imagine a firm facing an increase of energy price and wanting to adapt its production process with new technologies. Initially the direct impact of price is zero more whether its characteristics follow the average of the sample, then the firm does not have incentives to modify its level of investment. But suppose the level of energy consumption is so high that the higher energy price impact the production process. This becomes in an excuse to sacrifice investment and keep the production process in normal conditions. That is why the coefficient of REI is negative, against our preliminary expactation. A similar interpretation can be given for a higher capital intensity firm, with machinery that requires energy to work properly. This hypothesis is important since introduces the fact that a firm can have some kind of budget constraint that restricts the possibilities of adaptation. Indeed, a first approximation for this idea is the coefficient associated to the number of plants, a proxy variable for the size of the firm. The coefficient is negative and highly significant, which means that a higher number of plants, more difficult the investment spending. On the other side, the result given by the technological capability term results counterintuitive.

Another point to highlight is the more level of sensitiveness that GI has compared with RD. This is according to our hypothesis by considering that GI has a short-term component higher than RD, which is long term by nature, and to facilitate future spending on GI. This result is clearly reflected on the coefficients of TOTI. Adding the instrument does not change the main findings of the OLS regressions, except that the only significant interaction term is CAI, under the hypothesis already discussed. To summarize the result at the firm level, there is no direct effect of price, although it seems slightly positive, and it is only important when it interacts with other characteristics such as the capital intensity.

[19] Recognize that adding the interaction term implies that we add a new endogenous variable in the sample, but we gain one more instrument. That is the reason of why we study two specification for each interaction term: one for the price and other for the interaction

Table 1: OLS regressions at the firm level

	Dependent variable:														
	GI					RD					TOTI				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Energy Price	0.237	0.425	0.243	0.229	0.200	0.171	0.353	0.189	0.165	0.120	0.089	0.248	0.083	0.083	0.050
	(0.314)	(0.311)	(0.311)	(0.313)	(0.317)	(0.227)	(0.226)	(0.225)	(0.230)	(0.228)	(0.313)	(0.313)	(0.309)	(0.314)	(0.316)
Net Cons per W	0.459***	0.408***	0.457***	0.396***	0.447***	0.389***	0.339***	0.384***	0.344***	0.373***	0.517***	0.474***	0.518***	0.465***	0.504***
	(0.090)	(0.090)	(0.091)	(0.091)	(0.090)	(0.065)	(0.064)	(0.065)	(0.066)	(0.065)	(0.090)	(0.090)	(0.090)	(0.091)	(0.090)
Workers	0.089	0.104	0.089	0.093	0.098	0.089	0.104	0.091	0.092	0.102	0.128	0.142	0.128	0.132	0.139
	(0.093)	(0.093)	(0.094)	(0.092)	(0.093)	(0.063)	(0.064)	(0.064)	(0.063)	(0.063)	(0.098)	(0.098)	(0.099)	(0.098)	(0.098)
Inv per W	0.307***	0.312***	0.307***	0.291***	0.319***	0.172***	0.177***	0.172***	0.161***	0.188***	0.294***	0.299***	0.295***	0.281***	0.306***
	(0.080)	(0.079)	(0.080)	(0.080)	(0.080)	(0.062)	(0.061)	(0.062)	(0.062)	(0.062)	(0.081)	(0.081)	(0.081)	(0.082)	(0.081)
VETUS	−0.031	−0.040	−0.039	−0.167	0.077	−0.248	−0.257	−0.273	−0.344	−0.098	0.041	0.033	0.050	−0.070	0.156
	(0.469)	(0.469)	(0.468)	(0.465)	(0.451)	(0.335)	(0.331)	(0.337)	(0.331)	(0.321)	(0.456)	(0.456)	(0.456)	(0.455)	(0.443)
Plants	−0.162***	−0.163***	−0.162***	−0.161***	−0.161***	−0.105***	−0.107***	−0.105***	−0.105***	−0.105***	−0.192***	−0.193***	−0.192***	−0.191***	−0.191***
	(0.053)	(0.054)	(0.053)	(0.054)	(0.053)	(0.034)	(0.035)	(0.035)	(0.035)	(0.034)	(0.061)	(0.062)	(0.061)	(0.062)	(0.061)
REI		−0.307***					−0.298***					−0.259***			
		(0.081)					(0.061)					(0.074)			
SEI			−0.031					−0.098					0.036		
			(0.174)					(0.124)					(0.175)		
CAI				−0.785***					−0.554***					−0.636***	
				(0.138)					(0.107)					(0.130)	
TEC					1.830					2.535***					1.942*
					(1.173)					(0.830)					(1.087)
Constant	0.950***	0.753***	0.942***	0.777***	0.938***	0.680***	0.489***	0.656***	0.558***	0.663***	1.217***	1.051***	1.226***	1.077***	1.204***
	(0.159)	(0.165)	(0.160)	(0.160)	(0.159)	(0.117)	(0.120)	(0.117)	(0.116)	(0.116)	(0.175)	(0.181)	(0.175)	(0.176)	(0.175)
Firm FE	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083
Adjusted R^2	0.220	0.228	0.219	0.240	0.222	0.215	0.229	0.215	0.233	0.222	0.272	0.277	0.272	0.284	0.274

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. The estimation included fixed effects and qualitative variables ISO14, ISO50 and ICPE. All variables are logged except the qualitative ones. All columns are estimated with an OLS estimator without using instrumental variables. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is the only variable lagged one period.

Table 2: IV regressions at the firm level

	Dependent variable:														
	GI					RD					TOTI				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Energy Price	0.377	0.424	0.372	0.407	0.365	−0.267	−0.211	−0.253	−0.250	−0.320	−0.066	−0.111	−0.069	−0.046	−0.107
	(0.473)	(0.464)	(0.468)	(0.465)	(0.491)	(0.353)	(0.327)	(0.347)	(0.343)	(0.363)	(0.465)	(0.463)	(0.460)	(0.459)	(0.479)
Net Cons per W	0.488***	0.485***	0.492***	0.452***	0.485***	0.295***	0.292***	0.285***	0.275***	0.281***	0.483***	0.486***	0.485***	0.458***	0.473***
	(0.116)	(0.117)	(0.119)	(0.119)	(0.119)	(0.087)	(0.089)	(0.090)	(0.091)	(0.089)	(0.114)	(0.115)	(0.117)	(0.117)	(0.116)
Workers	0.101	0.106	0.101	0.108	0.103	0.049	0.054	0.051	0.052	0.055	0.114	0.110	0.114	0.119	0.119
	(0.098)	(0.098)	(0.098)	(0.097)	(0.097)	(0.066)	(0.065)	(0.067)	(0.065)	(0.065)	(0.101)	(0.102)	(0.102)	(0.101)	(0.101)
Inv per W	0.303***	0.303***	0.303***	0.290***	0.305***	0.187***	0.187***	0.187***	0.180***	0.198***	0.300***	0.300***	0.300***	0.291***	0.307***
	(0.080)	(0.080)	(0.080)	(0.080)	(0.080)	(0.063)	(0.063)	(0.063)	(0.062)	(0.064)	(0.082)	(0.082)	(0.082)	(0.082)	(0.082)
VETUS	−0.028	−0.029	−0.015	−0.121	−0.008	−0.257	−0.258	−0.296	−0.310	−0.166	0.037	0.038	0.045	−0.028	0.106
	(0.467)	(0.466)	(0.469)	(0.463)	(0.455)	(0.333)	(0.332)	(0.335)	(0.329)	(0.327)	(0.453)	(0.453)	(0.455)	(0.452)	(0.446)
Plants	−0.164***	−0.164***	−0.164***	−0.164***	−0.164***	−0.099***	−0.099***	−0.098***	−0.099***	−0.098***	−0.189***	−0.189***	−0.189***	−0.189***	−0.189***
	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.033)	(0.033)	(0.034)	(0.034)	(0.033)	(0.061)	(0.061)	(0.061)	(0.061)	(0.061)
REI		−0.045					−0.053					0.042			
		(0.135)					(0.111)					(0.128)			
SEI			0.051					−0.150					0.028		
			(0.222)					(0.166)					(0.232)		
CAI				−0.542**					−0.309*					−0.378*	
				(0.215)					(0.176)					(0.208)	
TEC					0.343					1.552					1.166
					(1.831)					(1.287)					(1.742)
Constant	0.944***	0.914***	0.956***	0.823***	0.941***	0.700***	0.665***	0.664***	0.631***	0.691***	1.225***	1.252***	1.232***	1.140***	1.218***
	(0.159)	(0.175)	(0.165)	(0.164)	(0.159)	(0.117)	(0.132)	(0.119)	(0.119)	(0.116)	(0.174)	(0.188)	(0.181)	(0.179)	(0.174)
Firm FE	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083
Adjusted R^2	0.220	0.221	0.219	0.238	0.220	0.212	0.216	0.211	0.227	0.217	0.272	0.270	0.272	0.282	0.273

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. The estimation included fixed effects and qualitative variables ISO14, ISO50 and ICPE. All variables are logged except the qualitative ones. All columns are estimated with an 2SLS estimator. The instrument and the first step regressions can be found in table 15. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is the only variable lagged one period.

4.3 The plant level: consistency of the effects

To study the consistency of the previous results, table 3 and 4 show the same regressions at the plant level. The results are particularly surprising by realizing that at this level both direct effect and the interaction terms are significant, and even adding the instrument, it amplifies the impact of price on investment. To talk about the magnitude, we are saying that whether the net energy consumption and the number of workers are in the average, an increase of 1% on energy prices increases GI on 0,8%, RD on 0,3% and TOTI on 0,7%. Again, the Porter's hypothesis appears without discarding the interaction effects are still important, particularly that related with the size of the plant (SEI).

As a secondary analysis, we estimated a model with random effects to test the validity of the results in table 5. For this estimation we exploit the fact that some plants belong to one specific firm, by adding this as a random effect. At the end, this model includes fixed effect term by sector and year, and the random effect by firm. Even if the significance of the results could be unreliable due to the estimation of mixed effects, those confirm the direction and magnitude of our initial estimations with OLS and IV regressions.

At this point, we can give some signs to the question of how energy prices influence the decision of environmental investment of firms and plants. Now, we may ensure that energy prices interact with other characteristics of the units to produce differentiated effects. In that way the effect is not homogeneous as initial approaches suggest. But this effect is not consistent at the firm and at the plant level given to the existence of a direct effect that is only significant and positive at the plant level, suggesting that there is other type of causes that modifies the interaction of price at the aggregated level. How can we explain this behavior? We introduce here the idea of a possible budget constraint phenomenon within firm, but not across plants.

Table 3: OLS regressions at the plant level

	Dependent variable:								
	GI			RD			TOTI		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Energy Price	0.456***	0.483***	0.489***	0.212*	0.232*	0.240**	0.387***	0.401***	0.417***
	(0.144)	(0.144)	(0.143)	(0.119)	(0.120)	(0.115)	(0.145)	(0.146)	(0.142)
Net Cons per W	0.600***	0.576***	0.597***	0.395***	0.378***	0.394***	0.621***	0.608***	0.619***
	(0.041)	(0.042)	(0.041)	(0.033)	(0.033)	(0.032)	(0.041)	(0.042)	(0.040)
Workers	0.774***	0.775***	0.760***	0.543***	0.544***	0.532***	0.884***	0.885***	0.872***
	(0.053)	(0.053)	(0.051)	(0.040)	(0.040)	(0.040)	(0.047)	(0.047)	(0.046)
REI		−0.107**			−0.077*			−0.058	
		(0.049)			(0.042)			(0.048)	
SEI			−0.541***			−0.445***			−0.489***
			(0.097)			(0.082)			(0.085)
Constant	4.992***	4.922***	4.869***	4.021***	3.971***	3.920***	5.128***	5.091***	5.017***
	(0.562)	(0.554)	(0.503)	(0.444)	(0.429)	(0.409)	(0.543)	(0.538)	(0.485)
Firm FE	N	N	N	N	N	N	N	N	N
Plant FE	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Division FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	6,476	6,476	6,476	6,476	6,476	6,476	6,476	6,476	6,476
Adjusted R^2	0.258	0.258	0.262	0.240	0.240	0.245	0.329	0.329	0.333

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. The estimation included fixed effects and qualitative variables ISO14, ISO50 and ICPE. All variables are logged except the qualitative ones. All columns are estimated with an OLS estimator without using instrumental variables. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is the only variable lagged one period.

Table 4: IV regressions at the plant level

	Dependent variable:								
	GI			RD			TOTI		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Energy Price	0.871***	0.831***	0.871***	0.363*	0.300	0.363*	0.718***	0.649***	0.719***
	(0.247)	(0.243)	(0.246)	(0.204)	(0.201)	(0.200)	(0.242)	(0.241)	(0.239)
Net Cons per W	0.680***	0.689***	0.672***	0.425***	0.439***	0.417***	0.685***	0.701***	0.676***
	(0.057)	(0.059)	(0.057)	(0.047)	(0.049)	(0.046)	(0.055)	(0.057)	(0.055)
Workers	0.812***	0.809***	0.794***	0.557***	0.553***	0.541***	0.915***	0.910***	0.896***
	(0.056)	(0.056)	(0.055)	(0.042)	(0.042)	(0.042)	(0.050)	(0.050)	(0.049)
REI		0.063			0.098			0.109	
		(0.074)			(0.063)			(0.072)	
SEI			−0.558***			−0.505***			−0.583***
			(0.143)			(0.126)			(0.133)
Constant	4.916***	4.961***	4.795***	3.994***	4.065***	3.884***	5.067***	5.146***	4.941***
	(0.530)	(0.539)	(0.478)	(0.438)	(0.459)	(0.404)	(0.516)	(0.534)	(0.457)
Firm FE	N	N	N	N	N	N	N	N	N
Plant FE	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Division FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	6,476	6,476	6,476	6,476	6,476	6,476	6,476	6,476	6,476
Adjusted R^2	0.256	0.255	0.261	0.239	0.237	0.245	0.329	0.327	0.332

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. The estimation included fixed effects and qualitative variables ISO14, ISO50 and ICPE. All variables are logged except the qualitative ones. All columns are estimated with an 2SLS estimator. The instrument and the first step regressions can be found in table 16. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is the only variable lagged one period.

Table 5: Mixed effects regressions at the plant level

	Dependent variable:								
	GI			RD			TOTI		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Energy Price	0.376***	0.403***	0.409***	0.172***	0.190***	0.197***	0.279***	0.296***	0.310***
	(0.028)	(0.029)	(0.029)	(0.028)	(0.029)	(0.029)	(0.028)	(0.029)	(0.029)
Net Cons per W	0.558***	0.535***	0.559***	0.361***	0.346***	0.362***	0.582***	0.568***	0.583***
	(0.007)	(0.008)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.008)	(0.007)
Workers	0.802***	0.801***	0.796***	0.551***	0.550***	0.547***	0.903***	0.903***	0.899***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
REI		−0.122***			−0.080***			−0.072***	
		(0.008)			(0.008)			(0.008)	
SEI			−0.563***			−0.416***			−0.482***
			(0.016)			(0.016)			(0.016)
Constant	4.317***	4.229***	4.115***	3.272***	3.215***	3.125***	4.235***	4.183***	4.052***
	(0.018)	(0.020)	(0.019)	(0.018)	(0.020)	(0.019)	(0.018)	(0.020)	(0.019)
Firm RE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Plant FE	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Division FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	6,476	6,476	6,476	6,476	6,476	6,476	6,476	6,476	6,476

Notes: *p<0.1; **p<0.05; ***p<0.01. The estimation included fixed effects and qualitative variables ISO14, ISO50 and ICPE. All variables are logged except the qualitative ones. All columns are estimated with a mixed effect estimator where the random effects are at firm level, and the fixed effect for year and division. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is the only variable lagged one period.

4.4 Robustness checks

Following the model 1, it is possible to exploit some features of the database and change the outcome variable for a dummy that explain the realization of a given type of investment. That means, a variable equal to one if the investment is larger than zero, and equal to zero is the investment does not take place. To do that, the estimation uses a logit model with robust errors at both levels. The results can be checked in tables 17 and 18 in the appendix. The results are similar to those obtained before.

5 The Budget Constraint Hypothesis

5.1 Hypothesis and methodology

The definition of a budget constraint, more than a theoretic model, corresponds to a direct phenomenon of a firm's management sphere. Defining it beyond the existence of a budget line requires understanding its implications for a manager's risk acquisition and the decision making process. One definition is given by Kornai et al. (2003), which consider that an organization has a budget constraint whether it must cover its expenditures out of its initial endowment and revenue. In their terms, "a constraint sets the upper limit on the sustainability of the financial deficit", and more than that, it conduces to reduce or cease its activity when the deficit persist without the support of an external organization [20].

Now, what does this phenomenon imply for the management of a firm? An answer can be found in Kornai (1979): "We can spend only as much money as we have. If we invest badly, we shall die of it". The expression, although colloquial, is appropriate to explain that a budget constraint implies responding to a higher level of risk by making the necessary adjustments to bring funds to the segments of the firm that are more efficient in terms of cost and benefit produced. The research about this point results abundant and quite relevant for our problem since it considers that budget constraint defines the destination, and even the quality of the measures or technologies adopted by the firms. That is the case with Hardy (1992) and Boyabatlı et al. (2016).

For our particular case, a breakdown of this behavior provides a first explanation of the inconsistency between firm and plant level. Consider a firm facing higher energy prices and wishing to invest in environmental technologies. Here it faces a debate as the higher price creates a budget constraint: either it maintains its energy consumption or it invests at the cost of a detriment of the production process. Previous estimates already give an indication of what is happening, i.e., the direct effect of the energy price. At the firm level, it is difficult to detect a direct price effect, beyond interactions with other visible characteristics. The opposite is true at the plant level where a positive and significant effect is detected following Porter's hypothesis. This means that the increase in investment at the aggregate level, i.e. the firm, is 0, while particular plants benefit from an increase. Going further, the management of each firm decides to sacrifice investment in some plants in order to allocate it to those where it is more efficient. That would be a possible reason why the effect on price is positive and significant, because we would be facing an increase more than proportional to the reduction of investment in other plants. In other words, the firm maintains the aggregate level of investment, but now allocates a greater amount of resources to some plants with some special characteristics.

Although the destination of the investment and the characteristics of those specific plants may be diverse, this paper evaluates one hypothesis in particular: the idea that investment increases in those plants that belong to a firm that are more energy intensive than the rest. This is quite coherent given that one of the main motives for executing this type of investment is precisely energy savings. To evaluate this, we use something we call the "ranking approach", including in the analysis the position of a plant compared to its peers with respect to the intensity of energy consumption. The methodology is straightforward. Within the firm, whether a plant has the highest energy intensity, it is assigned to the first position. If it has the second highest, it is assigned to the second position, and in that way the rest. To do that, we use as key variable the energy consumption per worker, as we made before to study the interaction terms, particularly REI.

However, this approach is not exempt from problems since a priori those firms that only have one plant are separated from the problem. This would be a difficulty if the database did not have the exact number of plants, something that does not happen with our sample. In fact, this is the first step of the methodology, studying the behavior of

[20] The literature characterizes this budget constraint as "hard", in contrast with "soft" budget constraints which correspond to those organizations that receive support from external entities as the state

single-plant and multi-plant firms. According to our hypothesis, their behavior must be differentiated since single-plant firms must follow a pattern much more similar to that of the sample of plants: single-plant firms do not face budget constraints. The second step results more complicated, since it consists in studying each plant according to its position in the ranking. The first approach consist on checking the absolute and marginal effects of energy price and consumption on investment by following a representative model. The idea is quite clear, an energy intense plant inside a firm must face a higher price and consumption effect compared with its peers. The second approach, easier, consist on estimating the impact of energy price on the difference of investment between the most and the less energy intensive plants. If the price is higher, and the investment goes to the most energy intensive plants, that difference must be higher. These two steps make this methodology a comprehensive approach since we study the two samples, at the plant level and at the firm level together.

5.2 The firm level: single-plant vs multi-plants firms

The budget constraint hypothesis with the given definition is only possible under the scenario that a firm has more than one plant. This is the only way for a restriction to take place, to the extent that a firm must decide which plant to invest in, under given characteristics. This is the interesting point of this section, to define where and why that investment is directed to a specific unit. Let us now think of a firm that only has one plant. Does Porter's hypothesis, that is, a positive effect of price on investment, work here? The idea is that in the face of a energy price shock, if the single-plant firm wants to save energy, it will clearly invest in that plant without any trade-off involved. In that case, the behavior must be quite similar to that seen in tables 3, 4 and 5 regarding the database at the plant level. To evaluate this, we make exactly the same regressions by separating the database at the firm level into these two types. The regressions by OLS can be seen in tables 6 and 8, while using the instrument in 7 and 9.

Table 6: OLS regressions for the single-plant firms

	Dependent variable:														
	GI					RD					TOTI				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Energy Price	0.625*	0.820**	0.576*	0.556*	0.584*	0.505**	0.684***	0.447*	0.458*	0.436*	0.496	0.672**	0.451	0.445	0.449
	(0.333)	(0.330)	(0.337)	(0.335)	(0.338)	(0.240)	(0.239)	(0.244)	(0.246)	(0.241)	(0.321)	(0.322)	(0.325)	(0.325)	(0.325)
Net Cons per W	0.540***	0.484***	0.523***	0.477***	0.530***	0.472***	0.421***	0.453***	0.430***	0.456***	0.595***	0.545***	0.580***	0.548***	0.584***
	(0.096)	(0.097)	(0.096)	(0.097)	(0.096)	(0.068)	(0.069)	(0.068)	(0.071)	(0.068)	(0.093)	(0.095)	(0.093)	(0.095)	(0.093)
Workers	0.448***	0.487***	0.483***	0.468***	0.454***	0.325***	0.360***	0.365***	0.338***	0.333***	0.542***	0.576***	0.573***	0.557***	0.548***
	(0.102)	(0.102)	(0.106)	(0.101)	(0.102)	(0.071)	(0.072)	(0.075)	(0.071)	(0.071)	(0.098)	(0.098)	(0.100)	(0.097)	(0.097)
Inv per W	0.241***	0.244***	0.241***	0.227***	0.250***	0.124*	0.127**	0.123*	0.115*	0.139**	0.207**	0.209**	0.206**	0.196**	0.216***
	(0.084)	(0.083)	(0.083)	(0.085)	(0.084)	(0.066)	(0.065)	(0.065)	(0.066)	(0.066)	(0.084)	(0.083)	(0.084)	(0.085)	(0.084)
VETUS	−0.322	−0.392	−0.401	−0.488	−0.255	−0.361	−0.426	−0.453	−0.473	−0.250	−0.387	−0.451	−0.459	−0.511	−0.310
	(0.497)	(0.503)	(0.498)	(0.499)	(0.485)	(0.363)	(0.361)	(0.361)	(0.361)	(0.356)	(0.471)	(0.476)	(0.471)	(0.474)	(0.464)
REI		−0.319***					−0.294***					−0.288***			
		(0.086)					(0.062)					(0.074)			
SEI			−0.463***					−0.538***					−0.420**		
			(0.191)					(0.165)					(0.181)		
CAI				−0.638***					−0.429***					−0.477***	
				(0.139)					(0.109)					(0.126)	
TEC					1.365					2.294					1.580
					(1.230)					(0.817)					(1.117)
Constant	0.938***	0.744***	0.857***	0.825***	0.926***	0.643***	0.464***	0.549***	0.567***	0.623	1.220***	1.044***	1.146***	1.136***	1.206***
	(0.130)	(0.138)	(0.132)	(0.129)	(0.130)	(0.099)	(0.102)	(0.098)	(0.097)	(0.097)	(0.139)	(0.147)	(0.144)	(0.140)	(0.139)
Firm FE	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	866	866	866	866	866	866	866	866	866	866	866	866	866	866	866
Adjusted R^2	0.266	0.274	0.270	0.280	0.267	0.278	0.291	0.288	0.289	0.284	0.339	0.346	0.342	0.346	0.340

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. The estimation included fixed effects and qualitative variables ISO14, ISO50 and ICPE. All variables are logged except the qualitative ones. All columns are estimated with an OLS estimator without using instrumental variables. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is the only variable lagged one period.

Table 7: IV regressions for the single-plant firms

	Dependent variable:														
	GI					RD					TOTI				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Energy Price	0.680	0.811*	0.635	0.649	0.674	0.120	0.215	0.035	0.106	0.085	0.436	0.510	0.384	0.416	0.415
	(0.477)	(0.472)	(0.488)	(0.480)	(0.482)	(0.349)	(0.334)	(0.359)	(0.350)	(0.353)	(0.463)	(0.464)	(0.474)	(0.466)	(0.468)
Net Cons per W	0.552***	0.532***	0.538***	0.507***	0.550***	0.390***	0.376***	0.364***	0.369***	0.381***	0.582***	0.571***	0.566***	0.554***	0.577***
	(0.119)	(0.121)	(0.121)	(0.125)	(0.120)	(0.088)	(0.090)	(0.091)	(0.094)	(0.089)	(0.115)	(0.116)	(0.117)	(0.120)	(0.115)
Workers	0.454***	0.477***	0.477***	0.472***	0.456***	0.285***	0.302***	0.328***	0.294***	0.295***	0.536***	0.548***	0.562***	0.547***	0.541***
	(0.108)	(0.108)	(0.109)	(0.106)	(0.107)	(0.076)	(0.075)	(0.075)	(0.074)	(0.075)	(0.103)	(0.104)	(0.104)	(0.102)	(0.103)
Inv per W	0.239***	0.239***	0.239***	0.227***	0.241***	0.138**	0.138**	0.138**	0.133**	0.150**	0.209**	0.209**	0.208**	0.201**	0.216***
	(0.084)	(0.083)	(0.083)	(0.085)	(0.083)	(0.067)	(0.066)	(0.066)	(0.066)	(0.067)	(0.084)	(0.084)	(0.084)	(0.085)	(0.083)
VETUS	−0.320	−0.354	−0.376	−0.452	−0.304	−0.369	−0.394	−0.474	−0.429	−0.271	−0.388	−0.407	−0.452	−0.471	−0.331
	(0.495)	(0.499)	(0.500)	(0.497)	(0.482)	(0.361)	(0.362)	(0.360)	(0.361)	(0.357)	(0.468)	(0.471)	(0.472)	(0.471)	(0.462)
REI		−0.155					−0.113					−0.088			
		(0.130)					(0.100)					(0.118)			
SEI			−0.322					−0.606***					−0.373		
			(0.297)					(0.214)					(0.282)		
CAI				−0.506***					−0.232					−0.320	
				(0.214)					(0.173)					(0.201)	
TEC					0.342					2.008*					1.172
					(1.704)					(1.201)					(1.606)
Constant	0.935***	0.838***	0.879***	0.844***	0.931***	0.668***	0.597***	0.563***	0.626***	0.648***	1.224***	1.169***	1.159***	1.166***	1.213***
	(0.131)	(0.149)	(0.139)	(0.133)	(0.131)	(0.100)	(0.113)	(0.100)	(0.100)	(0.099)	(0.140)	(0.157)	(0.149)	(0.144)	(0.140)
Firm FE	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	866	866	866	866	866	866	866	866	866	866	866	866	866	866	866
Adjusted R^2	0.266	0.272	0.269	0.279	0.266	0.276	0.284	0.285	0.285	0.282	0.339	0.342	0.342	0.346	0.340

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. The estimation included fixed effects and qualitative variables ISO14, ISO50 and ICPE. All variables are logged except the qualitative ones. All columns are estimated with an 2SLS estimator. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is the only variable lagged one period.

Table 8: OLS regressions for the multi-plant firms

	Dependent variable:														
	GI					RD					TOTI				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Energy Price	−0.948***	−0.688**	−1.698***	−0.048	−0.845**	−0.922***	−0.697***	−1.428***	−0.326	−0.828***	−1.048***	−0.817**	−1.929***	−0.164	−0.952***
	(0.333)	(0.330)	(0.337)	(0.335)	(0.338)	(0.240)	(0.239)	(0.244)	(0.246)	(0.241)	(0.321)	(0.322)	(0.325)	(0.325)	(0.325)
Net Cons per W	0.229**	0.162*	0.217**	0.217**	0.224**	0.125*	0.067	0.117*	0.117*	0.120*	0.301***	0.242**	0.287***	0.289***	0.296***
	(0.096)	(0.097)	(0.096)	(0.097)	(0.096)	(0.068)	(0.069)	(0.068)	(0.071)	(0.068)	(0.093)	(0.095)	(0.093)	(0.095)	(0.093)
Workers	−0.275***	−0.290***	−0.273***	−0.357***	−0.233**	−0.095	−0.109	−0.094	−0.150**	−0.058	−0.245**	−0.258***	−0.243**	−0.326***	−0.206**
	(0.102)	(0.102)	(0.106)	(0.101)	(0.102)	(0.071)	(0.072)	(0.075)	(0.071)	(0.071)	(0.098)	(0.098)	(0.100)	(0.097)	(0.097)
Inv per W	0.443***	0.469***	0.479***	0.429***	0.463***	0.255***	0.278***	0.280***	0.246***	0.274***	0.503**	0.526***	0.545***	0.489***	0.522***
	(0.084)	(0.083)	(0.083)	(0.085)	(0.084)	(0.066)	(0.065)	(0.065)	(0.066)	(0.066)	(0.084)	(0.083)	(0.084)	(0.085)	(0.084)
VETUS	0.125	0.361	0.327	0.346	0.543	−0.399	−0.195	−0.263	−0.253	−0.016	0.603	0.812*	0.839*	0.820*	0.993**
	(0.497)	(0.503)	(0.498)	(0.499)	(0.485)	(0.363)	(0.361)	(0.361)	(0.361)	(0.356)	(0.471)	(0.476)	(0.471)	(0.474)	(0.464)
REI		−0.429***					−0.372***					−0.382***			
		(0.086)					(0.062)					(0.074)			
SEI			0.418**					0.283*					0.491***		
			(0.191)					(0.165)					(0.181)		
CAI				−1.915***					−1.268***					−1.879***	
				(0.139)					(0.109)					(0.126)	
TEC					3.817***					3.499***					3.559***
					(1.230)					(0.817)					(1.117)
Constant	1.212***	0.567***	1.355***	0.225*	1.167***	0.835***	0.275***	0.931***	0.181*	0.794***	1.397***	0.824***	1.565***	0.428***	1.355***
	(0.130)	(0.138)	(0.132)	(0.129)	(0.130)	(0.099)	(0.102)	(0.098)	(0.097)	(0.097)	(0.139)	(0.147)	(0.144)	(0.140)	(0.139)
Firm FE	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217
Adjusted R^2	0.146	0.159	0.147	0.216	0.151 0.103	0.123	0.103	0.162	0.113	0.164	0.171	0.166	0.222	0.166	

Note: *p<0.1; **p<0.05; ***p<0.01

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. The estimation included fixed effects and qualitative variables ISO14, ISO50 and ICPE. All variables are logged except the qualitative ones. All columns are estimated with an OLS estimator without using instrumental variables. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is the only variable lagged one period.

Table 9: IV regressions for the multi-plant firms

	Dependent variable:														
	GI					RD					TOTI				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Energy Price	0.261	−0.610	−0.794	0.803*	0.669	−0.714**	−1.430***	−1.989***	−0.403	0.232	−0.511	−1.679***	−2.060***	−0.087	0.134
	(0.477)	(0.472)	(0.488)	(0.480)	(0.482)	(0.349)	(0.334)	(0.359)	(0.350)	(0.353)	(0.463)	(0.464)	(0.474)	(0.466)	(0.468)
Net Cons per W	0.484***	0.492***	0.433***	0.481***	0.598***	0.169*	0.175*	0.107	0.166*	0.432***	0.414***	0.424***	0.339***	0.411***	0.594***
	(0.119)	(0.121)	(0.121)	(0.125)	(0.120)	(0.088)	(0.090)	(0.091)	(0.094)	(0.089)	(0.115)	(0.116)	(0.117)	(0.120)	(0.115)
Workers	−0.203*	−0.207*	−0.211*	−0.250**	−0.215**	−0.083	−0.086	−0.093	−0.110	−0.111	−0.213**	−0.218**	−0.225**	−0.250**	−0.232**
	(0.108)	(0.108)	(0.109)	(0.106)	(0.107)	(0.076)	(0.075)	(0.075)	(0.074)	(0.075)	(0.103)	(0.104)	(0.104)	(0.102)	(0.103)
Inv per W	0.406***	0.379***	0.453***	0.397***	0.369***	0.249***	0.227***	0.306***	0.244***	0.164**	0.486***	0.451***	0.556***	0.480***	0.428***
	(0.084)	(0.083)	(0.083)	(0.085)	(0.083)	(0.067)	(0.066)	(0.066)	(0.066)	(0.067)	(0.084)	(0.084)	(0.084)	(0.085)	(0.083)
VETUS	0.077	−0.276	0.319	0.205	−0.376	−0.408	−0.698*	−0.115	−0.334	−1.457***	0.581	0.108	0.937**	0.681	−0.135
	(0.495)	(0.499)	(0.500)	(0.497)	(0.482)	(0.361)	(0.362)	(0.360)	(0.361)	(0.357)	(0.468)	(0.471)	(0.472)	(0.471)	(0.462)
REI		0.677***					0.557***					0.908***			
		(0.130)					(0.100)					(0.118)			
SEI			0.489*					0.590***					0.717**		
			(0.297)					(0.214)					(0.282)		
CAI				−1.118***					−0.641***					−0.874***	
				(0.214)					(0.173)					(0.201)	
TEC					−3.939**					−9.134***					−6.232***
					(1.704)					(1.201)					(1.606)
Constant	1.102***	2.161***	1.284***	0.524***	1.101***	0.816***	1.688**	1.037***	0.485***	0.815***	1.348***	2.769***	1.617***	0.897***	1.348***
	(0.131)	(0.149)	(0.139)	(0.133)	(0.131)	(0.100)	(0.113)	(0.100)	(0.100)	(0.099)	(0.140)	(0.157)	(0.149)	(0.144)	(0.140)
Firm FE	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217
Adjusted R^2	0.134	0.042	0.138	0.191	0.090	0.102	−0.032	0.097	0.146	−0.107	0.162	0.039	0.164	0.202	0.103

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. The estimation included fixed effects and qualitative variables ISO14, ISO50 and ICPE. All variables are logged except the qualitative ones. All columns are estimated with an 2SLS estimator. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is the only variable lagged one period.

The results of these regressions are not entirely different from those found with the database at the complete firm level. However, interaction effects deserve more detail, since they allow us to better understand the problem we are facing:

- Regarding the raw interaction terms, again the capital intensity effect seems to be the most important in terms of significance in both subsamples. Definitely, this confirms the existence of differentiated effects, regardless of the number of plants within a firm.

- The role of energy consumption is attractive given its level of significance, but more than that, its interaction with price. Note that this interaction is only significant for multi-plant firms, a sign of a possible hidden relationship of these firm with the energy intensity level. This can confirm the existence of some phenomena such as our budget constraint.

- The most important aspect refers to the direct effect of price. Even though it is not completely significant for both subsamples, there is a interesting pattern of positive coefficients in the single-plant subsample and negative in the multi-plant one. That means that the direct effect of price seems to be differentiated and in line with what was seen before with the estimates at the plant level.

This pattern seems to indicate that Porter's hypothesis holds for those single-plant firms, which by the way do not face budget constraints as previously described. With this it can be concluded that the main cause of the divergence of results between the plant level and the firm level is precisely the different behavior of the multi-plant firms. That is where the research should focus.

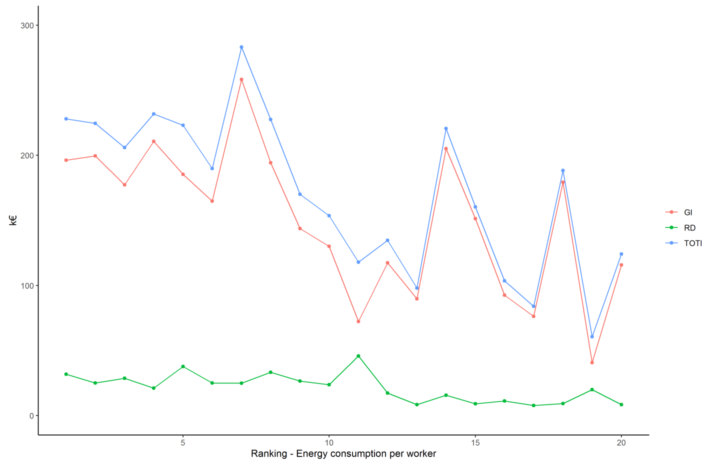
5.3 The plant level: ranking approach

Considering only the multi-plant firms sample allows to study the pattern of investment depending on the characteristics of each plant involved. Under our expectation, and continuing with the idea of the existence of a budget constraint, a multi-plant firm must take a decision about the destination of investment according to some characteristics of the investment. It is coherent to think that those firms will decide about the best destination in terms of costs and benefits with an increase of price. Some signs can be found on the own characteristics of that kind of investment, by supporting a technology that usually saves energy or prevent more pollution, or in the extreme case, promoting research to make easier future adoptions. What would a firm do in that scenario? It is hard to say given that the managerial decisions are quite heterogeneous and follow a logic that is not necessarily trending. Our work as researchers would then consist of discussing possible hypotheses and studying their validity according to the availability of data. The document follows this methodology

Our hypothesis is as follows. If a multi-plant firm faces an increase of energy price, it will increase the EI in those plants that are more intense in terms of energy. This makes more sense that a global increase of investment across plants, since the firm faces budget constraints. This idea is not contrary to Porter's hypothesis since it considers precisely improvements on the the productivity and efficiency of firms. Obviously this implies making the best decision in terms of the benefit and the cost of each investment.

As we discussed before, we use as proxy of energy intensity the energy consumption per worker. Under our hypothesis, those plants within a firm with higher energy consumption per worker could be more sensible to increases of energy price. With that in mind, the ranking approach not only is pertinent, but very flexible to study the behavior of those particular units since we can make some statistics in function of that position in the ranking. We can start the discussion by saying that the level of investment could be higher for those plants located in the first positions no matters the type. Figure 1 presents the average level of investment per plant according to its position in the energy intensity consumption: a decreasing trend respecting the position in the ranking following our initial expectation [21]. However, it is necessary to analyze the level of sensitivity with which the investment directed to these plants changes with respect to shocks both in the price and in energy consumption, to this we refer to the absolute and marginal effects, and how they are related to the position in the ranking.

Figure 1: Plant average investment according to the energy intensity ranking



Notes: Author's calculation based on the energy intensity ranking within multi-plant firms.

5.3.1 Absolute and marginal effects

Studying the absolute and marginal effects implies taking as reference one of the models estimated before for the equation 1. For this case, we use the model estimated with random effects estimated in 5 (the second model that presents the REI term) since it gives a better fit compared with the other empirical specifications and the traditional information criteria. In order to study these effects we take the estimated coefficients as given as well as GI as the main outcome variable of interest [22]. The description of each effect is given below:

- We refer to an absolute effect the raw contribution of a variable when the value

[21] This graphic analysis should be done with caution since the sample is not representative depending on the number of plants. By way of example, not all firms have more than 20 plants, only those classified as large. In addition, the sample does not include all the firms that have more than 20 plants. That is why the information can lose generality as the number of plants within a firm increases. This explains some of the spikes in the figure above.

[22] The figures regarding RD and TOTI as outcome variables can be checked in the appendix

of others is given. For our case, when P is the energy price and T the energy consumption per worker, the absolute effects of those variables are respectively:

$$APE_{it} = \beta_1 P_{it-1} + \beta_3 P_{it-1} T_{it} \tag{2}$$

$$ACE_{it} = \beta_2 T_{it} + \beta_3 P_{it-1} T_{it} \tag{3}$$

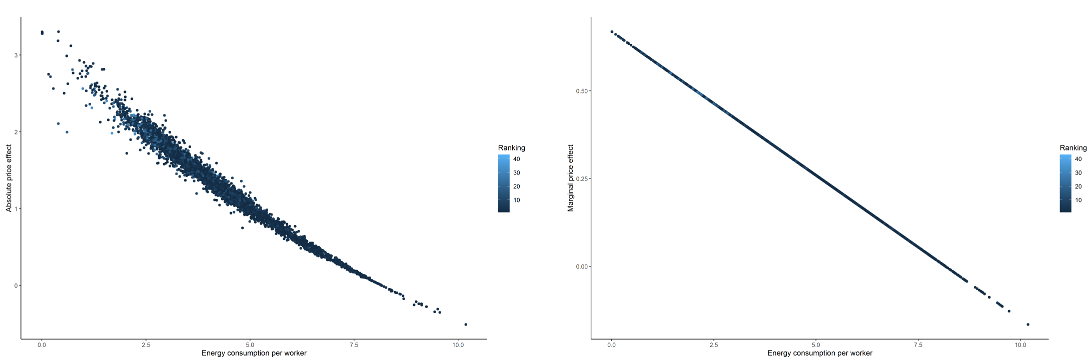
- We refer to a marginal effect the marginal contribution of a variable when the value of the others is given. It corresponds to the first derivative respect to the variable of interest of equation 1. For our case, the marginal effect of energy price and consumption iare respectively:

$$MPE_{it} = \beta_1 + \beta_3 T_{it} \tag{4}$$

$$MCE_{it} = \beta_2 + \beta_3 P_{it-1} \tag{5}$$

Under a budget constraint hypothesis, the relation between the effect and the position of the ranking depends on the variable of interest. If we are talking about consumption, the absolute and marginal contribution of this variable to the level of investment must be higher for the plants in the first position of the ranking by definition, and more than that, due to the estimated coefficient, positive and significant. But the story changes regarding energy price since the contribution must be lower for those in the first positions. This is because those plants must be less sensitive to changes on energy price. As we mentioned before, the firm will sacrifice investment on those plants with a lower level of energy intensity since investing in them does not represent immediate benefit. The energy price contribution (or sensitivity) must be higher on them. Analysing this graphically results easy by simply putting together both the effects and the level of consumption per worker, while reviewing their position in the ranking. Figures 2 and 3 do that for the case of GI, although no trend can be easily identifiable.

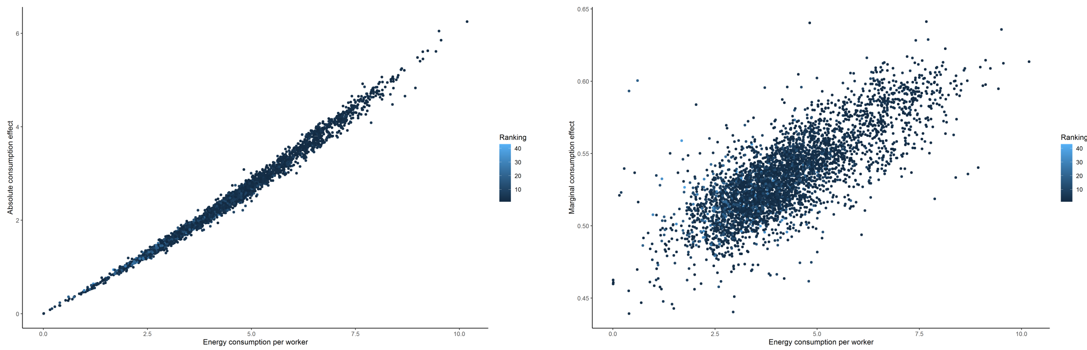
Figure 2: Price effect and energy consumption per worker for GI



(a) Absolute price effect (b) Marginal price effect

Notes: Author's calculation based on the regressions estimated in 5. The x axis refers to the energy consumption per workers, while the y axis are the price effects. The color of each point is determined by the position of the energy intensity ranking within firm.

Figure 3: Consumption effect and energy consumption per worker for GI

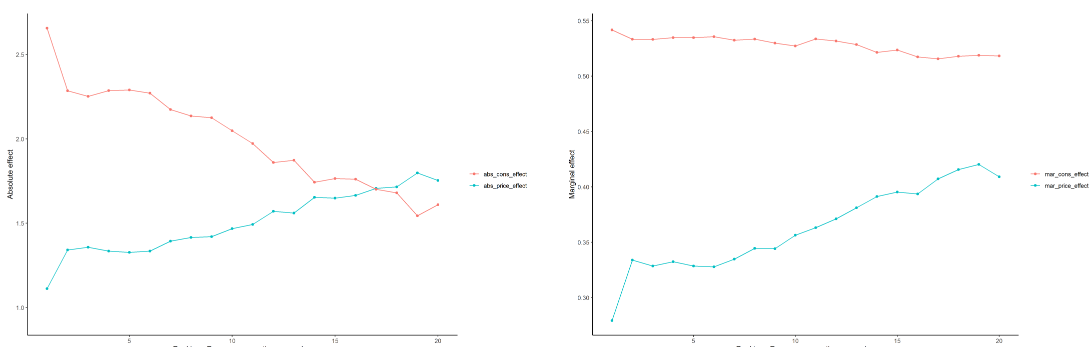


(a) Absolute consumption effect (b) Marginal consumption effect

Notes: Author's calculation based on the regressions estimated in 5. The x axis refers to the energy consumption per workers, while the y axis are the price effects. The color of each point is determined by the position of the energy intensity ranking within firm.

A different way to analyze these effects is simply to calculate the average effect for each position in the ranking, and test whether the trends follow the hypothesis provided previously. Figure 4 does that, and indeed, it confirms our initial expectation. Lower price effects and higher consumption effects for more energy intense plants. This clearly confirms that the investment behavior between the plants of a firm is heterogeneous, and responds to particular characteristics such as the level of energy intensity. It remains to be tested whether these differences are significant to allocate a higher level of investment in plants with greater energy intensity, and whether this is precisely due to price increases. This is the subject of the next section.

Figure 4: GI average effects according to the energy intensity ranking



(a) Absolute effect (b) Marginal effect

Notes: Author's calculation based on the regressions estimated in 5. The x axis is the position in the ranking, while the y axis are the price effects. The color of each point is determined by the position of the energy intensity ranking within firm.

5.3.2 Differences of investment among plants

To recap, this paper has established a positive causal relationship between the price of energy and the different levels of investment for two particular databases: (1) at the plant level, and (2) in those single-plant firms. We also managed to establish a special sensitivity for those plants with the most intense energy in multi-plant firms. But this analysis is more descriptive than causal since it does not give any signals respect to the movement of investment facing a price shock. Once again, the key lies in the ranking approach as it is possible to establish direct relationships between the plants within the firm.

How would change the investment in multi-plant firms with a higher energy price? Since the firm faces a budget constraint, it will displace more investment to those plants that are first in the ranking, sacrificing those that do not represent an improvement in energy consumption in the short term. Thus, there will be a gap in real investment between the most energy intensive plant and the least intensive one. In this way, the objective becomes to test the existence of this gap agreeing both the firm and the plant level. In fact, this is a new way of testing Porter's hypothesis in an environment with uncertainty and risk like the one faced by the managers of these firms. Finding a positive impact of the price on the gap means that it does increase investment, but only in those energy intensive plants.

For this new specification, we regress the next equation at the firm level but regarding only the most energy intensive plant and the less intensive one in a multi-plant firm. This changes the databases considered before. The equation to estimate is:

$$DIFF_{it} = \alpha_0 + \alpha_1 P_{it-1} + \epsilon \tag{6}$$

Where $DIFF_{it}$ is the investment difference among the most energy intensive and the less intensive plant in the multi-plant firm i at time t, and P_{it-1} is the energy price this firm faces. We refer for investment the different definitions given before: GI, RD and TOTI. This specification include year fixed effects. Furthermore, it is possible to use the same instrument for energy price. Table 10 shows the results.

Table 10: Differences of investment among plants

	Dependent variable:					
	OLS			IV		
	(GI)	(RD)	(TOTI)	(GI)	(RD)	(TOTI)
Energy Price	803.865	82.971*	886.836	815.175	150.621*	965.796
	(851.249)	(47.455)	(868.078)	(837.582)	(78.068)	(860.949)
Constant	−100.682	−42.598*	−143.281	−101.605	−48.119*	−149.725
	(81.718)	(25.132)	(96.517)	(86.995)	(26.632)	(104.493)
Firm FE	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y
Observations	198	198	198	198	198	198
Adjusted R^2	0.002	0.036	0.010	0.002	0.027	0.010

Note: *p<0.1; **p<0.05; ***p<0.01

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. The estimation does not include other control variables more that year fixed effects. All columns are estimated with an OLS estimator or a 2SLS estimator without using instrumental variables. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is lagged one period.

Table 10 shows a rather important result. The impact of the energy price on the investment gap is positive, although it only tends to be significant when we talk about RD as the output variable. In better terms, faced with an increase in the price of energy, a multi-plant firm will increase investment in the most energy-intensive plant. This confirms and revalidates Porter's hypothesis regarding a direct impact of price on investment.

It is also pertinent to make some comments regarding the magnitude of the price shock. The OLS estimate seems to underestimate this impact, an aspect that becomes evident with the instrumental variable estimation. This is important since in the estimation using the data at the firm level as a whole this effect seems to be diluted, leading to the erroneous conclusion that the effect is minuscule, or simply null.

6 Concluding Remarks and Further Research

This paper starts with a quite general question: How do energy prices influence green investment decisions of firms and plants? An answer that requires posing some hypotheses about the managerial behavior of each firm, and how resources are distributed among plants. Initially, the question is to determine the existence of a direct effect of the price of energy on investment, an aspect that has been well studied in the literature through case studies, for instance, Dussaux (2020) and Marin and Vona (2021) with France, as this paper does. This direct effect can be positive or negative, whether it responds to a greater willingness to adopt new technologies that allow energy savings, or to a mere constraint that prevents greater investment to keep energy consumption and the production process stable. But the literature has always focused on this positive relationship, through the so-called Porter hypothesis, which in a competitive environment would promote the distribution of resources in more efficient areas, whether as a result of a price increase or a regulatory measure. In the end, firms respond to incentives and price is still one of them.

However, finding this causal result may not be simple, and some of the research overlooks the fact that the impact on price is not necessarily homogeneous, and may respond to both firm and plant characteristics. We are referring to the fact that price may interact with other variables such as energy consumption, capital intensity, size or the age of the machines, an **interaction** effect that allows reaching different results and not Porter's result itself. In fact, these differential effects, and further, the different nature of observational units, may be responsible for the lack of **consistency** in the results, in our particular case, at the firm level and at the plant level. Although this difference is not uncommon in the literature, it is strange to generalize a result without explaining the causes that trigger it. In this paper we found a divergence between the non-significant direct impact of energy prices on investment at the firm level and the positive and significant impact at the plant level, and explaining this inconsistency thus becomes the priority and the main contribution of this article.

Finding an explanation is difficult unless a hypothesis is put forward in advance. The approach proposed here is simple: if there is no aggregate price impact (at the firm level) but there is a specific impact (at the plant level), it is because the firm must distribute its scarce resources among its plants if the price of energy increases. If this were to be true, the aggregate impact would be zero because there is no direct increase in the level of investment, but positive and highly significant for some plants that see a more than proportional increase in their available resources. We call this the **budget constraint hypothesis**. Obviously this has consequences for the treatment of the databases, for example, when differentiating between single-plant and multi-plant firms.

But detecting the presence of a budget constraint does not close the research question since it is necessary to investigate the destination of this new investment, i.e., the characteristic of the plants to which it is directed. By the given definition of the different types of environmental investment, we evaluate the possible hypothesis that such investment is directed to the energy intensive plants within a firm. This is because the investment is made precisely to reduce the pollution generated or to save energy. In fact, we find that with an increase in the price of energy, the difference between the investment of the most energy-intensive plant and the least energy-intensive one tends to grow. This conclusion is quite powerful since Porter's hypothesis holds despite the null effect that may exist in first estimates. The incentive to invest exists, it is just that it is not easy to detect the paths to where it takes place.

Thus, this paper advances the related literature precisely by studying **interaction** effects, **consistency** of results and the possible **budget constraint**, three expressions that in fact summarize the work presented here. It is imperative to mention that the results presented here do not deny, but helps to explain discrepancies found in Dussaux (2020) and Marin and Vona (2021) regarding the aggregation and the chain that explains the behavior between firms and plants.This document also gives possible solutions to the problems discussed by Fu et al. (2018), for instance, interaction effects. The opportunity for improvement and further research is possible by studying hypotheses in addition to the budget constraint such as strategic behaviors between firms and plants, or the existence of mimicry between units in the same sector. It should be noted that the estimates presented here refer only to the manufacturing sector, so the results are not fully generalized. On the other hand, there are many empirical approximations that could be exploited, given the availability of data and the time horizon. Binary models are a very interesting opportunity, as was studied by Hammar and Åsa Löfgren (2010). Research should be directed in that direction, without ignoring that there may be other behaviors different from what Porter defends with his position: the positive impact of price on investment. As we have seen here, this behavior is not only conjunctural and responds to quite specific incentives and characteristics.

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7 Appendix

7.1 Summary statistics, correlations and graphics

7.1.1 Firm level

Table 11: Summary statistics

Variable	N	Mean	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
GI	7803	1.056	1.996	0	0	1.121	9.568
RD	7803	0.638	1.4	0	0	0	9.156
TOTI	7803	1.34	2.138	0	0	2.785	9.632
GI_D	7803	0.267	0.442	0	0	1	1
RD_D	7803	0.207	0.405	0	0	0	1
TOTI_D	7803	0.339	0.473	0	0	1	1
Energy Price	3917	4.206	0.337	2.848	4.015	4.424	6.102
Net Consumption	7803	8.808	2.134	0.693	7.432	10.195	16.088
Energy Use per Worker	7803	3.603	1.34	0.008	2.749	4.34	9.554
Workers	7803	5.285	1.281	1.792	4.394	6.086	10.663
Tangible Investment per Worker	7803	2.157	0.978	0	1.481	2.801	9.011
VETUS	7785	0.684	0.143	0.008	0.608	0.783	1
Plants	7803	2.321	3.51	1	1	2	49
ISO14	7803	0.409	0.492	0	0	1	1
ISO50	7670	0.167	0.373	0	0	0	1
ICPE	7803	0.709	0.454	0	0	1	1

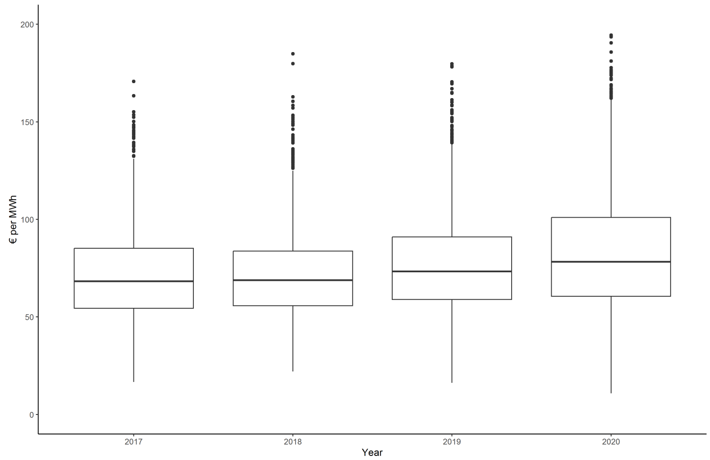
Notes: The unit of observation is the firm. It includes the three levels of investment GI, RD and TOTI as well as a dummy variable equal to 1 if the firm makes a positive investment (variable followed by a D). Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Net consumption includes only the purchased quantity of energy without self production. ISO14, ISO50 and ICPE refer to environmental certifications. All the variables are logged.

Table 12: Correlations

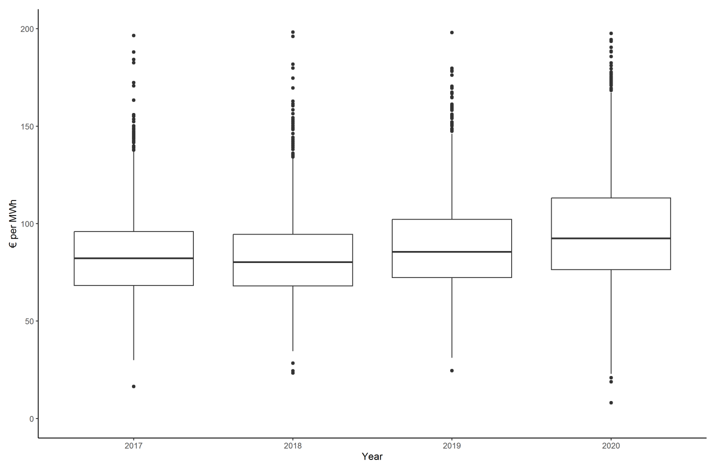
	Energy Price	Net Consumption	Energy Use per Worker	Workers	Tangible Investment per Worker	VETUS	Plants
GI	-0.265	0.253	0.295	0.095	0.253	-0.085	-0.108
RD	-0.263	0.244	0.285	0.093	0.218	-0.081	-0.088
TOTI	-0.299	0.286	0.330	0.110	0.272	-0.085	-0.121

Notes: Pearson correlations using only those pairs with complete information at the firm level.

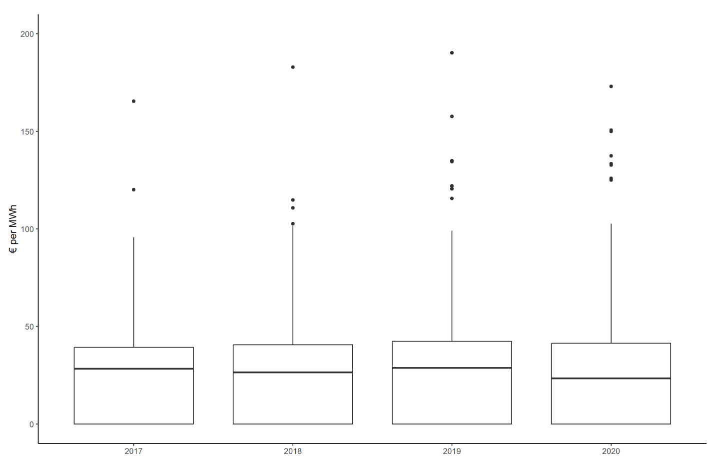
Figure 5: Distribution price per year



(a) Total



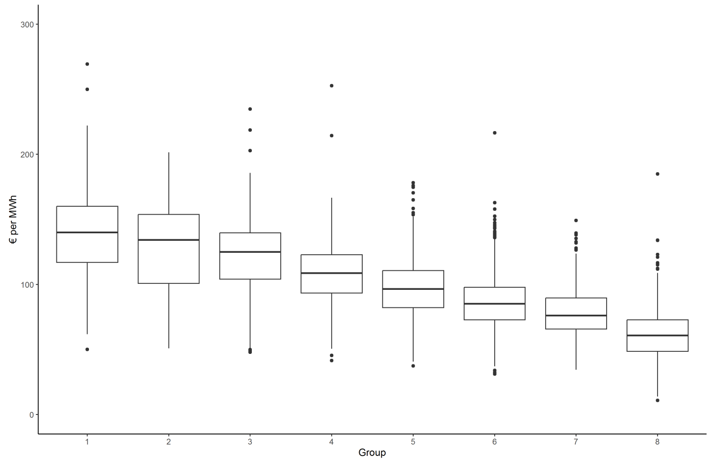
(b) Electricity



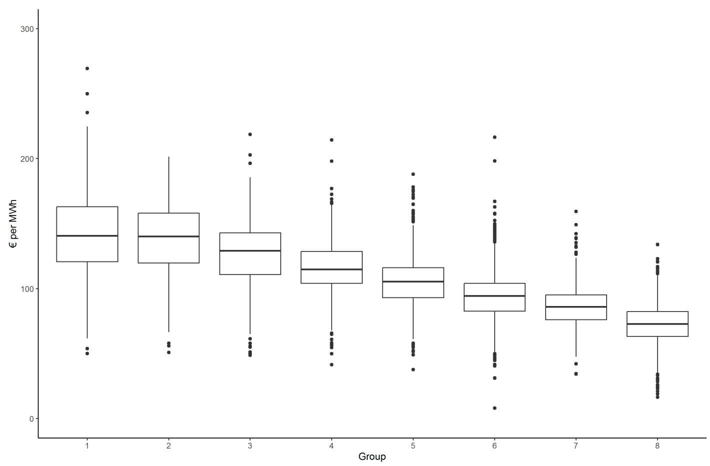
(c) Gas

Notes: Author's calculation using information at the firm level and the energy price index as euros per MWh. Source: EACEI.

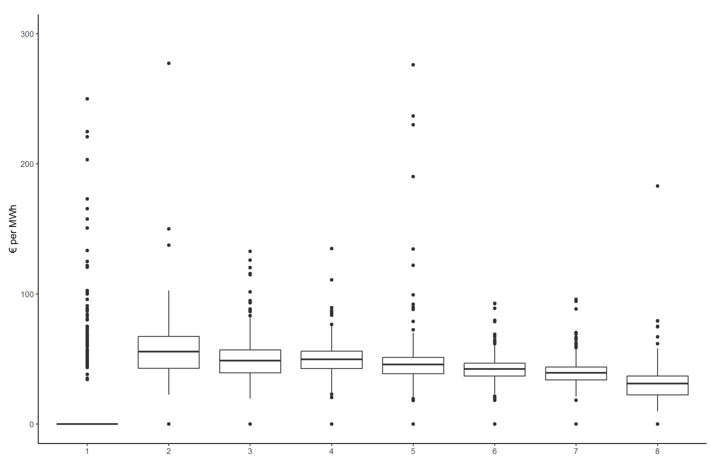
Figure 6: Distribution price per consumption group



(a) Total



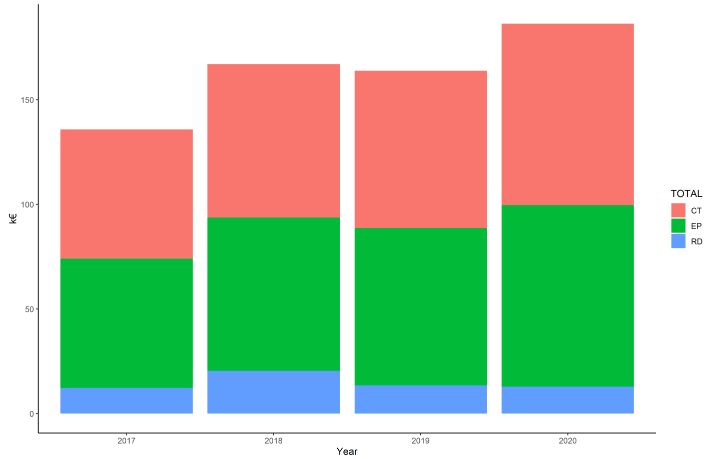
(b) Electricity



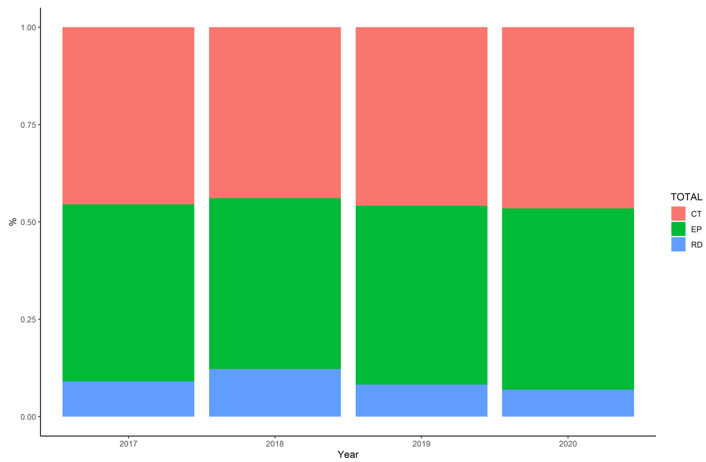
(c) Gas

Notes: Author's calculation using information at the firm level and the energy price index as euros per MWh. The groups of consumption are defined as follows: (1) less o equal than 50 MWh, (2) greater than 50 MWh and less o equal than 100 MWh, (3) greater than 100 MWh and less o equal than 250 MWh, (4) greater than 250 MWh and less o equal than 500 MWh, (5) greater than 500 MWh and less o equal than 1000 MWh, (6) greater than 1000 MWh and less o equal than 2500 MWh, (7) greater than 2500 MWh and less o equal than 5000 MWh, and (8) greater than 5000 MWh. Source: EACEI.

Figure 7: Investment behavior per year



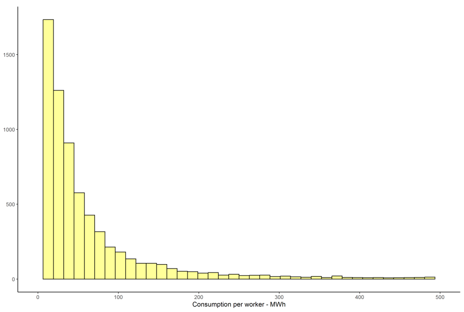
(a) Thousand of euros



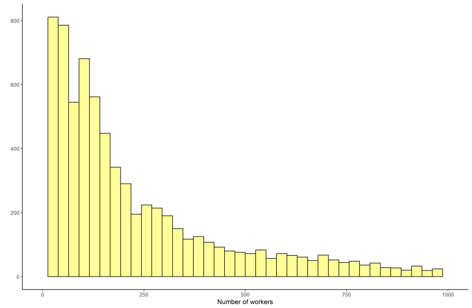
(b) Percent of the total

Notes: Author's calculation using information at the firm level and investment as thousand of euros. Source: ANTIPOL.

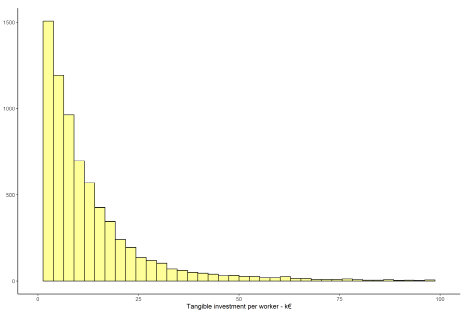
Figure 8: Histogram of control variables



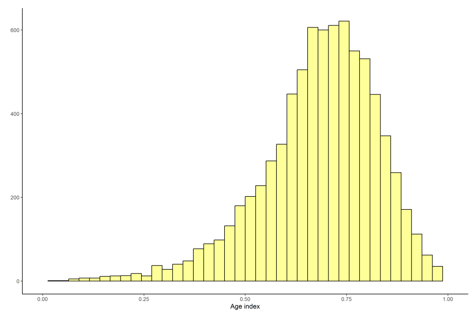
(a) Net Consumption



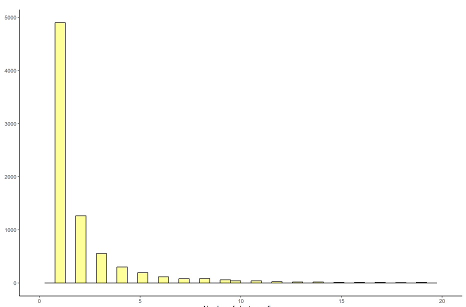
(b) Workers



(c) Tangible Investment per Worker



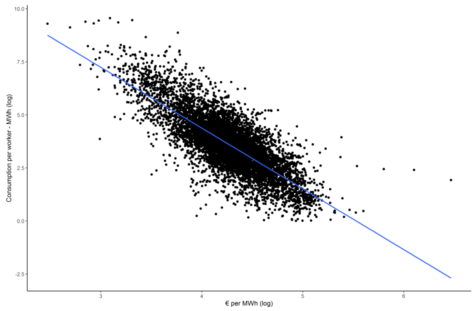
(d) VETUS



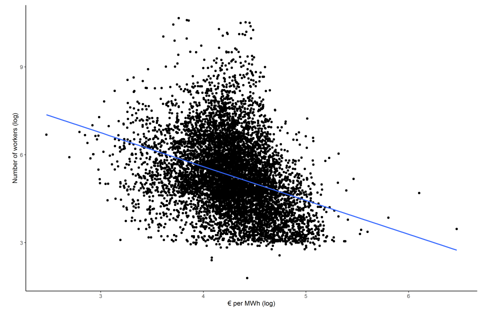
(e) Plants

Notes: Author's calculation using information at the firm level.

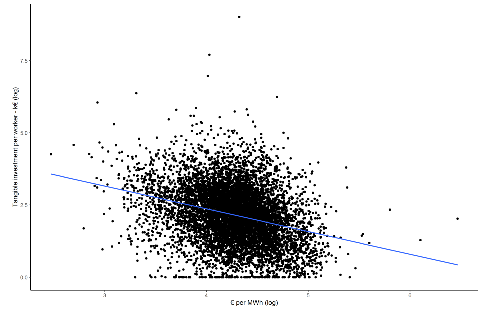
Figure 9: Relation between total energy price and control variables



(a) Net Consumption



(b) Workers



(c) Tangible Investment per Worker

Notes: Author's calculation using information at the firm level. Energy price as euros per MWh is included in the X axis, while the control variables in the y axis. All the variables are logged.

7.1.2 Plant level

Table 13: Summary statistics

Variable	N	Mean	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
GI	12513	2.01	2.385	0	0	3.956	9.797
RD	12513	1.179	1.687	0	0	2.501	9.154
TOTI	12513	2.437	2.397	0	0	4.364	9.81
GI_D	12513	0.502	0.5	0	0	1	1
RD_D	12513	0.387	0.487	0	0	1	1
TOTI_D	12513	0.604	0.489	0	0	1	1
Energy Price	6476	4.08	0.353	2.726	3.873	4.31	6.102
Net Consumption	12513	9.061	1.902	0.693	7.898	10.231	15.52
Energy use per worker	12511	3.919	1.469	0.007	2.968	4.697	10.185
Workers	12513	5.207	0.95	0	4.644	5.802	9.616
ISO14	12513	0.458	0.498	0	0	1	1
ISO50	12446	0.183	0.387	0	0	0	1
ICPE	12513	0.784	0.412	0	1	1	1

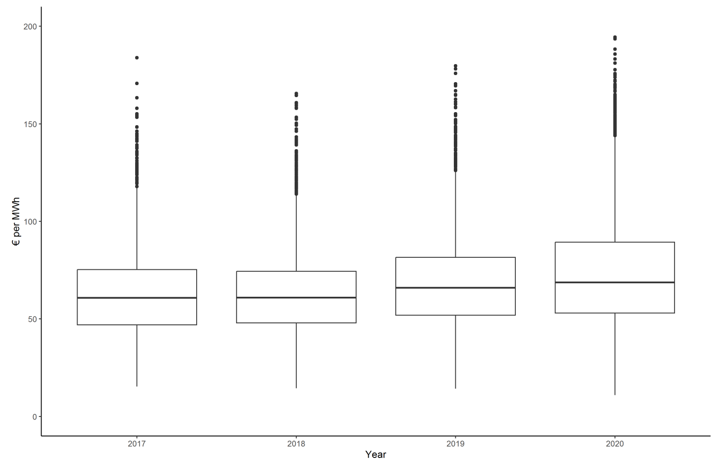
Notes: The unit of observation is the plant. It includes the three levels of investment GI, RD and TOTI as well as a dummy variable equal to 1 if the firm makes a positive investment (variable followed by a D). Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Net consumption includes only the purchased quantity of energy without self production. ISO14, ISO50 and ICPE refer to environmental certifications. All the variables are logged.

Table 14: Correlations

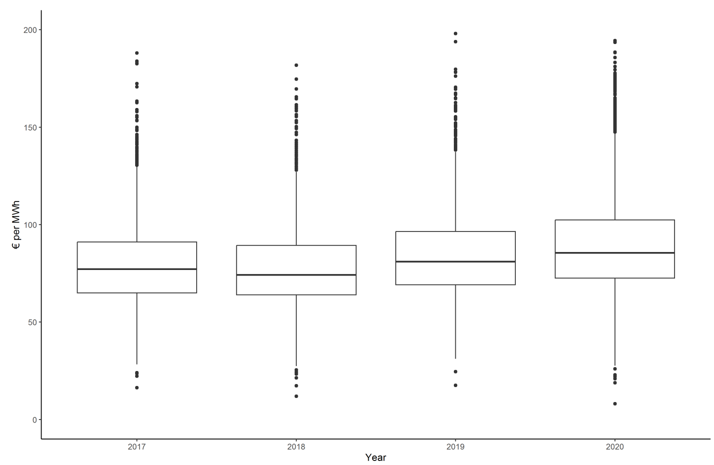
	Energy Price	Net Consumption	Energy use per worker	Workers
GI	-0.265	0.253	0.295	0.095
RD	-0.263	0.244	0.285	0.093
TOTI	-0.299	0.286	0.330	0.110

Notes: Pearson correlations using only those pairs with complete information at the plant level.

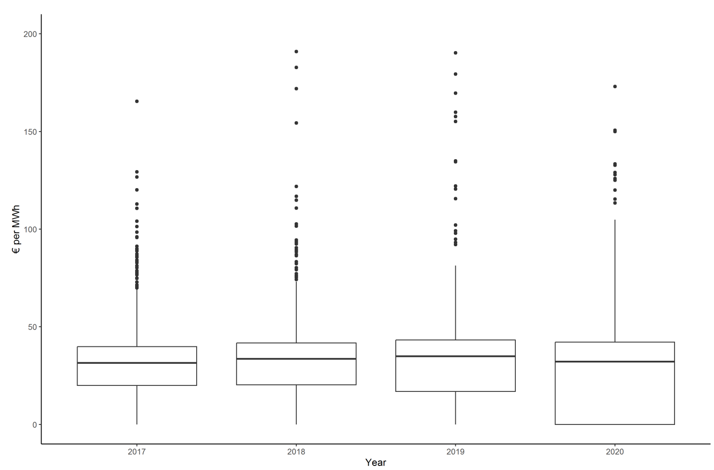
Figure 10: Distribution price per year



(a) Total



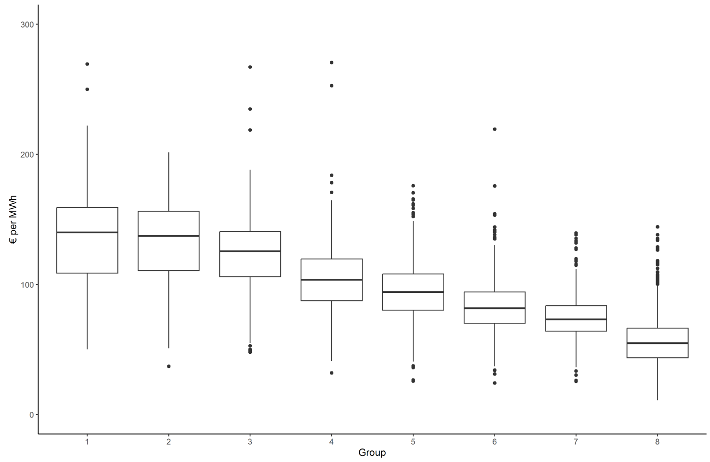
(b) Electricity



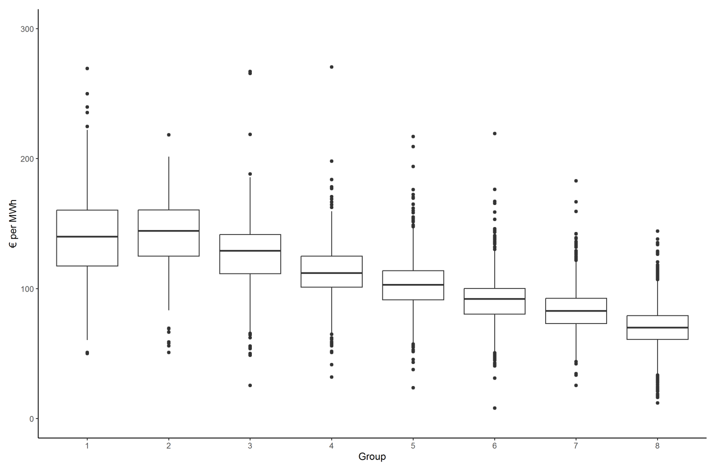
(c) Gas

Notes: Author's calculation using information at the plant level and the energy price index as euros per MWh. Source: EACEI.

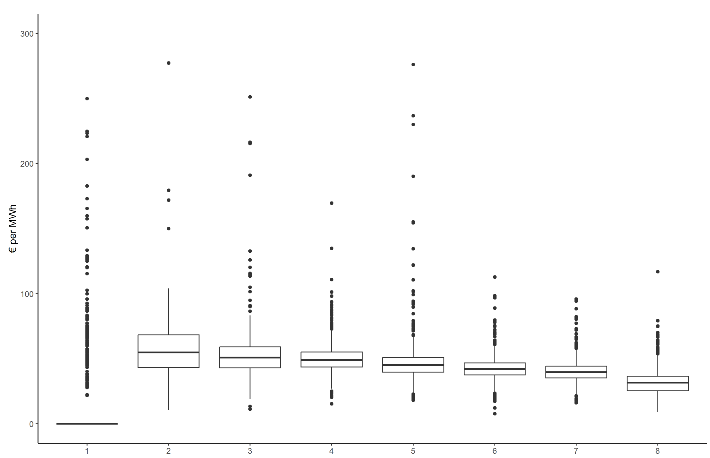
Figure 11: Distribution price per consumption group



(a) Total



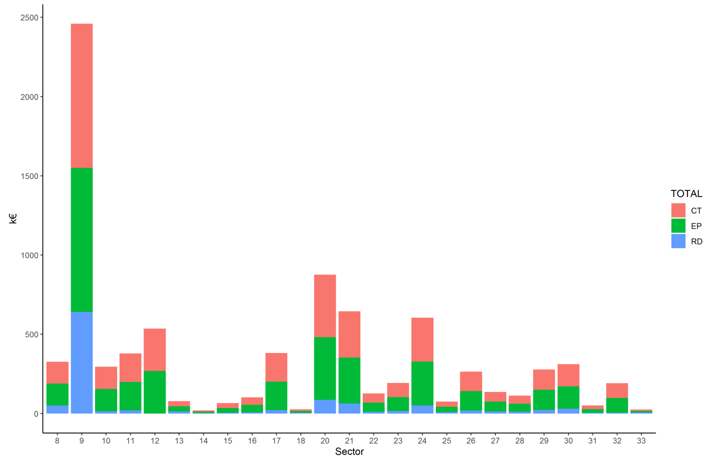
(b) Electricity



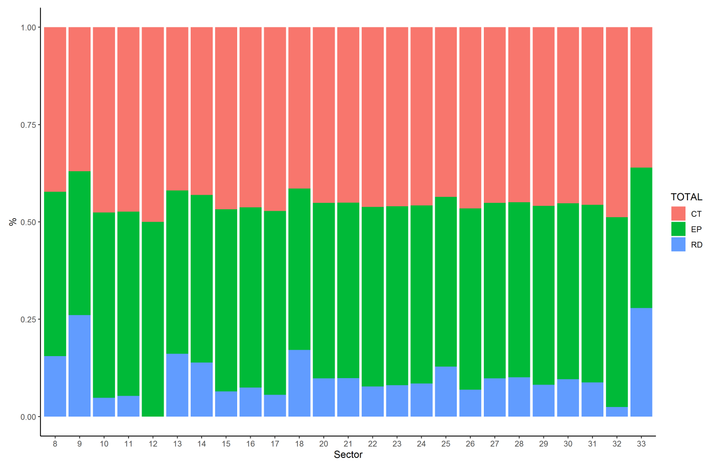
(c) Gas

Notes: Author's calculation using information at the plant level and the energy price index as euros per MWh. The groups of consumption are defined as follows: (1) less o equal than 50 MWh, (2) greater than 50 MWh and less o equal than 100 MWh, (3) greater than 100 MWh and less o equal than 250 MWh, (4) greater than 250 MWh and less o equal than 500 MWh, (5) greater than 500 MWh and less o equal than 1000 MWh, (6) greater than 1000 MWh and less o equal than 2500 MWh, (7) greater than 2500 MWh and less o equal than 5000 MWh, and (8) greater than 5000 MWh. Source: EACEI.

Figure 12: Investment behavior per sector



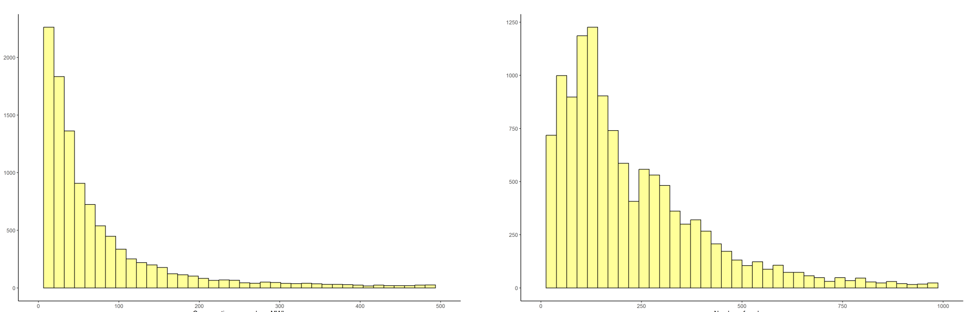
(a) Thousand of euros



(b) Percent of the total

Notes: Author's calculation using information at the plant level and investment as thousand of euros. The averages are computed for each 2-digit industry know as division according to the NAF, *nomenclature d'activités française*. Source: ANTIPOL.

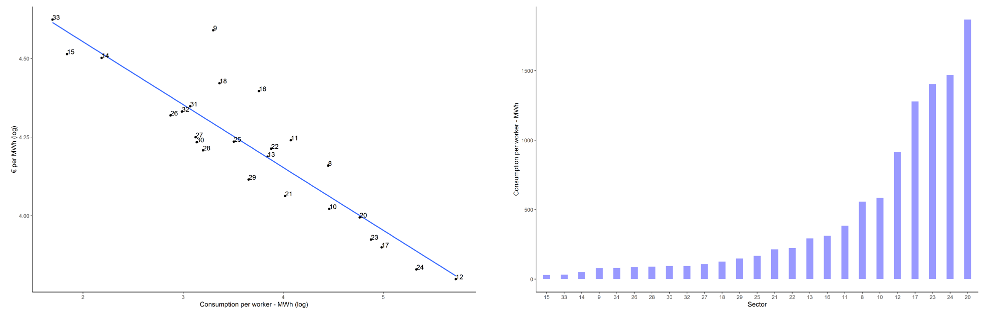
Figure 13: Histogram of control variables



(a) Net Consumption (b) Workers

Notes: Author's calculation using information at the plant level.

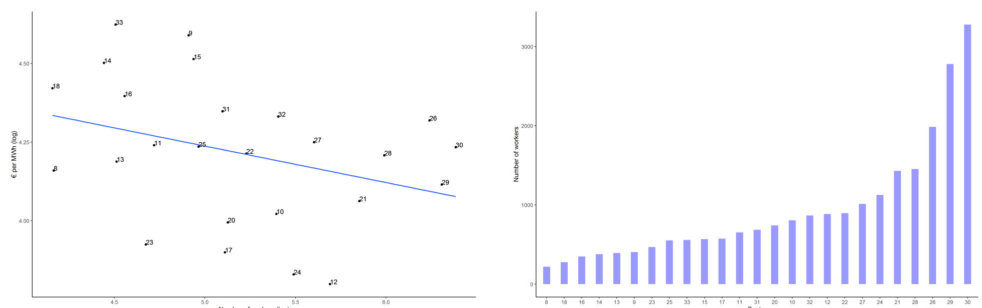
Figure 14: Behavior of net consumption per sector



(a) Relation with total energy price (b) Average per sector

Notes: Author's calculation using information at the plant level the averages are computed for each 2-digit industry know as division according to the NAF, *nomenclature d'activités française*.

Figure 15: Behavior of number of workers per sector



(a) Relation with total energy price (b) Average per sector

Notes: Author's calculation using information at the plant level the averages are computed for each 2-digit industry know as division according to the NAF, *nomenclature d'activités française*.

7.2 Auxiliary regressions and robust checks

7.2.1 Relevance of the instrument

Table 15: First stage regressions at the firm level

	Dependent variable:								
	Energy Price	REI		SEI		CAI		TEC	
	(EP)	(EP)	(IT)	(EP)	(IT)	(EP)	(IT)	(EP)	(IT)
Energy Price IV	0.641***	0.637***	−0.193**	0.648***	−0.192***	0.648***	−0.094	0.640***	0.020**
	(0.027)	(0.028)	(0.093)	(0.027)	(0.054)	(0.027)	(0.058)	(0.027)	(0.009)
REI IV		0.004	1.144***						
		(0.015)	(0.079)						
SEI IV				−0.031	1.095***				
				(0.023)	(0.077)				
CAI IV						−0.058***	1.005***		
						(0.019)	(0.073)		
TEC IV								0.208	0.943***
								(0.134)	(0.065)
Constant	0.088***	0.089***	−0.370***	0.085***	−0.141***	0.086***	−0.190***	0.087***	0.006
	(0.015)	(0.015)	(0.046)	(0.015)	(0.028)	(0.014)	(0.027)	(0.015)	(0.004)
Firm FE	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083
Adjusted R^2	0.809	0.809	0.634	0.810	0.541	0.811	0.517	0.810	0.451

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. EP refers to the specification with energy price as endogenous variable. IT is the endogenous interaction term. Both are part of the first stage regressions only when an interaction term is used in the main specification.

Table 16: First stage regressions at the plant level

	Dependent variable:				
	Energy Price	REI		SEI	
	(EP)	(EP)	(IT)	(EP)	(IT)
Energy Price IV	0.662***	0.630***	−2.196***	0.798***	−1.357***
	(0.016)	(0.041)	(0.197)	(0.078)	(0.469)
REI IV		0.007	1.164***		
		(0.008)	(0.050)		
SEI IV				−0.026*	0.911***
				(0.015)	(0.095)
Constant	2.413***	2.540***	13.088***	1.856***	10.875***
	(0.120)	(0.192)	(0.862)	(0.324)	(1.937)
Firm FE	N	N	N	N	N
Plant FE	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y
Division FE	Y	Y	Y	Y	Y
Observations	6,476	6,476	6,476	6,476	6,476
Adjusted R^2	0.794	0.794	0.974	0.794	0.946

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. EP refers to the specification with energy price as endogenous variable. IT is the endogenous interaction term. Both are part of the first stage regressions only when an interaction term is used in the main specification.

7.2.2 Robust checks - Binary regressions

Table 17: Binary regressions at the firm level

	Dependent variable:														
	GI					RD					TOTI				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Energy Price	0.444	0.589	0.459	0.474	0.456	0.591*	0.747*	0.646*	0.623*	0.580	0.065	0.142	0.050	0.067	0.073
	(0.352)	(0.372)	(0.353)	(0.355)	(0.353)	(0.358)	(0.391)	(0.360)	(0.359)	(0.360)	(0.350)	(0.367)	(0.350)	(0.350)	(0.353)
Net Cons per W	0.342***	0.318***	0.340***	0.321***	0.346***	0.497***	0.471***	0.492***	0.487***	0.493***	0.331***	0.320***	0.334***	0.324***	0.334***
	(0.098)	(0.098)	(0.099)	(0.099)	(0.099)	(0.098)	(0.099)	(0.098)	(0.099)	(0.098)	(0.099)	(0.099)	(0.099)	(0.100)	(0.099)
Workers	0.401***	0.417***	0.404***	0.409***	0.401***	0.556***	0.570***	0.558***	0.558***	0.556***	0.487***	0.496***	0.482***	0.490***	0.486***
	(0.113)	(0.113)	(0.113)	(0.113)	(0.113)	(0.117)	(0.117)	(0.116)	(0.117)	(0.116)	(0.117)	(0.117)	(0.117)	(0.117)	(0.117)
Inv per W	0.226***	0.232***	0.227***	0.218**	0.223**	0.212**	0.217**	0.212**	0.202**	0.216**	0.202**	0.206**	0.201**	0.202**	0.199**
	(0.087)	(0.087)	(0.087)	(0.089)	(0.086)	(0.092)	(0.092)	(0.092)	(0.093)	(0.092)	(0.091)	(0.091)	(0.091)	(0.091)	(0.090)
VETUS	0.322	0.322	0.316	0.283	0.261	−0.255	−0.262	−0.269	−0.272	−0.169	0.382	0.384	0.391	0.365	0.355
	(0.524)	(0.529)	(0.524)	(0.528)	(0.533)	(0.519)	(0.521)	(0.519)	(0.519)	(0.554)	(0.530)	(0.532)	(0.531)	(0.530)	(0.533)
Plants	−1.265***	−1.281***	−1.280***	−1.282***	−1.267***	−1.198***	−1.209***	−1.240***	−1.202***	−1.196***	−1.320***	−1.331***	−1.304***	−1.329***	−1.321***
	(0.174)	(0.175)	(0.179)	(0.173)	(0.173)	(0.195)	(0.196)	(0.207)	(0.195)	(0.195)	(0.174)	(0.176)	(0.179)	(0.175)	(0.175)
REI		−0.177					−0.159					−0.111			
		(0.117)					(0.127)					(0.115)			
SEI			−0.080					−0.214					0.084		
			(0.226)					(0.245)					(0.222)		
CAI				−0.442**					−0.195					−0.190	
				(0.187)					(0.213)					(0.196)	
TEC					−0.619					0.686					−0.437
					(1.234)					(1.392)					(1.320)
Constant	−0.284	−0.361	−0.282	−0.329	−0.281	−0.683*	−0.754**	−0.671*	−0.702*	−0.685*	0.200	0.160	0.195	0.190	0.203
	(0.325)	(0.336)	(0.326)	(0.332)	(0.324)	(0.358)	(0.365)	(0.363)	(0.361)	(0.359)	(0.307)	(0.313)	(0.306)	(0.309)	(0.307)
Firm FE	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. The estimatio included fixed effects and qualitative variables ISO14, ISO 50 and ICPE. All variables are logged except the qualitative ones. All columns are estimated with a logit estimator without using instrumental variables. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is the only variable lagged one period.

Table 18: Binary regressions at the plant level

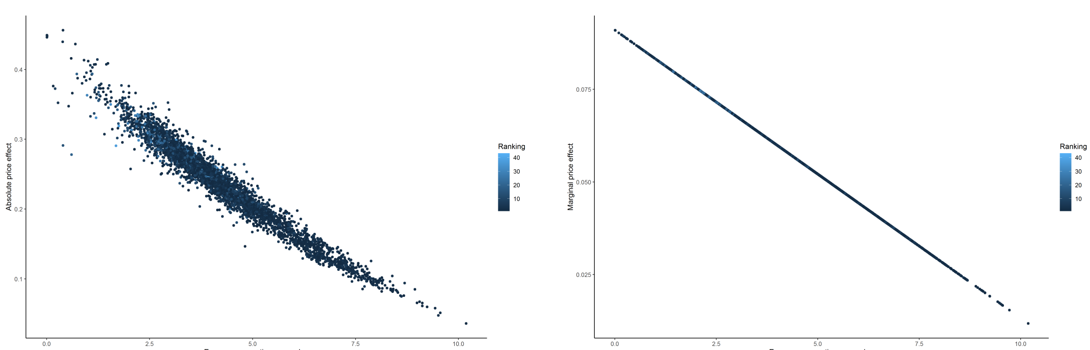
	Dependent variable:								
	GI			RD			TOTI		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Energy Price	0.317**	0.301**	0.323**	0.190	0.173	0.210	0.151	0.146	0.147
	(0.149)	(0.149)	(0.149)	(0.159)	(0.161)	(0.159)	(0.165)	(0.165)	(0.165)
Net Cons per W	0.346***	0.355***	0.347***	0.357***	0.364***	0.359***	0.357***	0.362***	0.358***
	(0.042)	(0.043)	(0.042)	(0.044)	(0.046)	(0.044)	(0.048)	(0.048)	(0.048)
Workers	0.520***	0.519***	0.519***	0.545***	0.544***	0.541***	0.697***	0.696***	0.700***
	(0.055)	(0.055)	(0.055)	(0.057)	(0.057)	(0.057)	(0.062)	(0.062)	(0.063)
REI		0.055			0.038			0.035	
		(0.055)			(0.060)			(0.063)	
SEI			−0.072			0.038			−0.079
			(0.112)			(0.120)			(0.134)
Constant	12.572***	12.606***	12.555***	12.487***	12.514***	12.456***	12.554***	12.573***	12.531***
	(0.556)	(0.543)	(0.534)	(0.550)	(0.563)	(0.542)	(0.576)	(0.583)	(0.571)
Firm FE	N	N	N	N	N	N	N	N	N
Plant FE	N	N	N	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Division FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	6,476	6,476	6,476	6,476	6,476	6,476	6,476	6,476	6,476

Notes: Robust standard errors clustered at the firm level in parentheses. *p<0.1; **p<0.05; ***p<0.01. The estimatio included fixed effects and qualitative variables ISO14, ISO 50 and ICPE. All variables are logged except the qualitative ones. All columns are estimated with a logit estimator without using instrumental variables. Energy price is the weighted average energy cost in electricity and natural gas in thousands of euros per megawatt hour (MWh), where the weights are the ratio between the quantity purchased for that specific source and the total. Energy price is the only variable lagged one period.

7.3 Absolute and marginal effects

7.3.1 RD

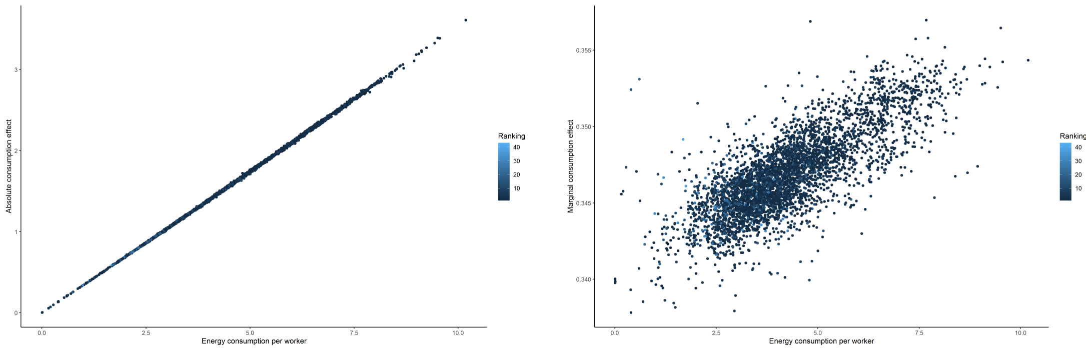
Figure 16: Price effect and energy consumption per worker for RD



(a) Absolute price effect (b) Marginal price effect

Notes: Author's calculation based on the regressions estimated in 5. The x axis refers to the energy consumption per workers, while the y axis are the price effects. The color of each point is determined by the position of the energy intensity ranking within firm.

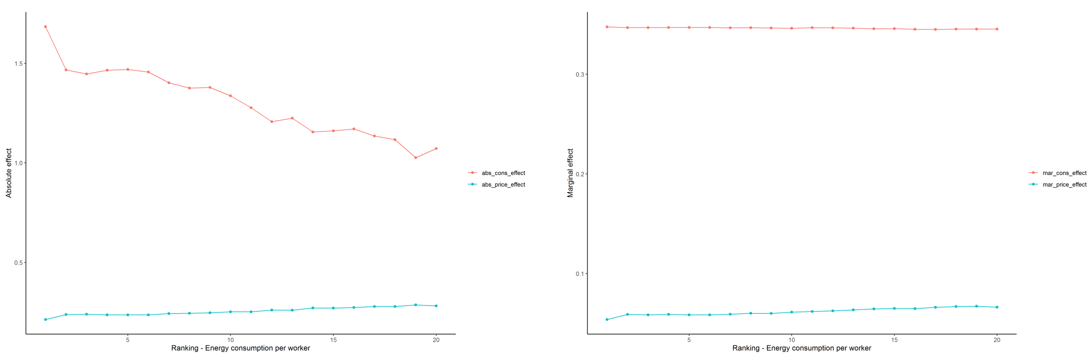
Figure 17: Consumption effect and energy consumption per worker for RD



(a) Absolute consumption effect (b) Marginal consumption effect

Notes: Author's calculation based on the regressions estimated in 5. The x axis refers to the energy consumption per workers, while the y axis are the price effects. The color of each point is determined by the position of the energy intensity ranking within firm.

Figure 18: RD average effects according to the energy intensity ranking

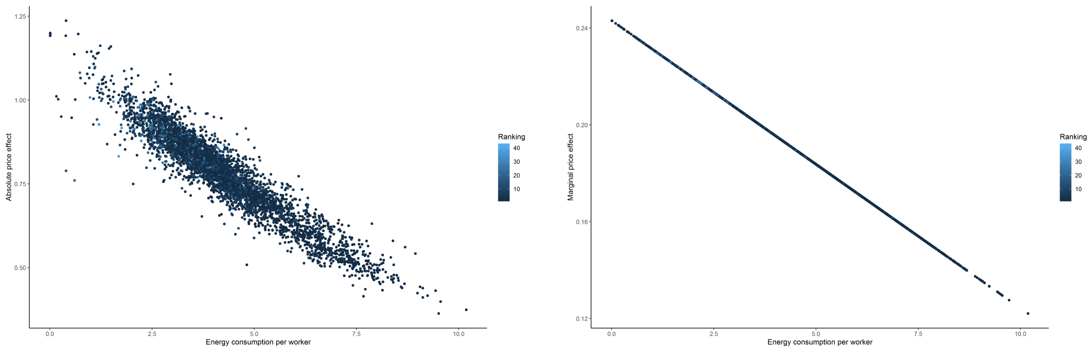


(a) Absolute effect (b) Marginal effect

Notes: Author's calculation based on the regressions estimated in 5. The x axis is the position in the ranking, while the y axis are the price effects. The color of each point is determined by the position of the energy intensity ranking within firm.

7.3.2 TOTI

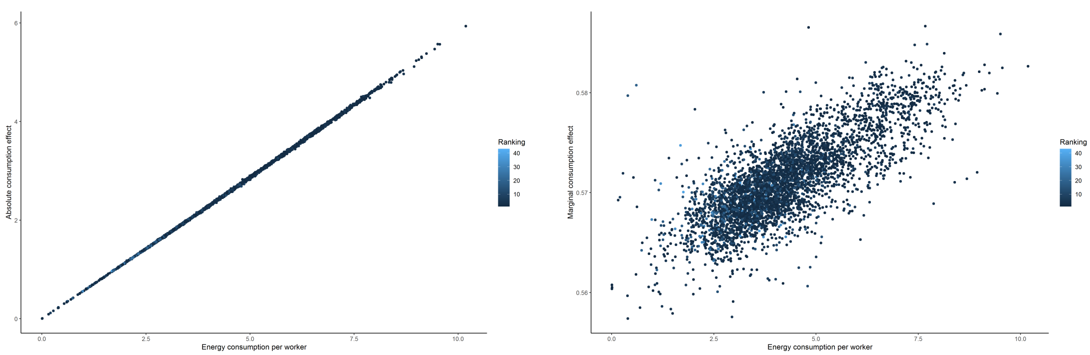
Figure 19: Price effect and energy consumption per worker for TOTI



(a) Absolute price effect (b) Marginal price effect

Notes: Author's calculation based on the regressions estimated in 5. The x axis refers to the energy consumption per workers, while the y axis are the price effects. The color of each point is determined by the position of the energy intensity ranking within firm.

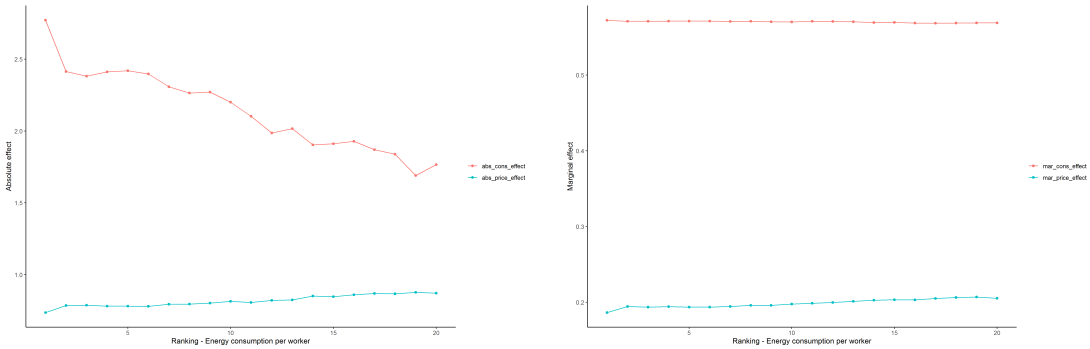
Figure 20: Consumption effect and energy consumption per worker for TOTI



(a) Absolute consumption effect (b) Marginal consumption effect

Notes: Author's calculation based on the regressions estimated in 5. The x axis refers to the energy consumption per workers, while the y axis are the price effects. The color of each point is determined by the position of the energy intensity ranking within firm.

Figure 21: TOTI average effects according to the energy intensity ranking



(a) Absolute effect

(b) Marginal effect

Notes: Author's calculation based on the regressions estimated in 5. The x axis is the position in the ranking, while the y axis are the price effects. The color of each point is determined by the position of the energy intensity ranking within firm.