Energy mix and intensity in Portugal: Portraits from aggregate and firm-level data

João Amador
Banco de Portugal
Nova School of Business and Economics

January 2022

Abstract
This article presents the path of several aggregate energy indicators for Portugal and the Euro area in the last three decades. In addition, we use Portuguese firm-level data on electricity and liquid fuels expenditures to assess firms' electrification and efficiency, while also correlating those indicators with their size. The article ultimately aims at shedding light on the pace of transformation towards an electrically driven, renewable and energy efficient economy. Overall, we identify some progress in the renewable-based electrification of the Portuguese and Euro area economies, as well as sizeable progress in energy intensity in Portugal since the mid 2000s. Moreover, controlling for firms' heterogeneity, we find a robust negative correlation between energy intensity and firms' size and partial evidence of a negative correlation between the share of electricity on total energy expenditures and firms' size. Finally, we identify a negative correlation between the share of electricity on firms' energy expenditure and their energy intensity ratio. (JEL: Q40, L21, L25)

1. Introduction

Energy is indispensable for economic activity. Indeed, every single human activity requires some degree of energy consumption and it is hard to conceive the full impact in our lives of a continued collapse in energy supply. Nowadays, energy price hikes coupled with the need to restructure the energy sector and consumption patterns in order to phase out fossil fuels and meet targets for greenhouse gas reductions, have brought the topic to the forefront of economic debate.

The impact of energy prices and their pass-through on inflation dynamics is well known. Supply shortages due to geopolitical developments, natural disasters or the simple exertion of market power by producers, in a context where the demand curve is relatively rigid, lead to price spikes. These increases do not affect core inflation unless they are sustained and feed into expectations and wage updates. In this article we do not directly discuss the link between energy and inflation but we assess the dependence of

Acknowledgements: The author is thankful to Nuno Alves, António Antunes, Joana Garcia, Carlos Gouveia, Pedro Duarte Neves, Ana Catarina Pimenta and Cátia Silva for their very useful comments and suggestions. The opinions expressed are those of the author and do not necessarily coincide with those of Banco de Portugal or the Eurosystem.

E-mail: jamador@bportugal.pt

the Portuguese and euro area economies on external energy supplies, which is a measure of exposure to some of the referred risks. In addition, we analyse the primary energy mix, which depends on the natural conditions of countries and also has a bearing on their ability to diversify energy supply risks and manage prices.

The link between our analysis, the green transition and climate change challenges is tighter. By assessing the share of renewable-based electricity on the total amount of energy consumed in the economy we can infer how far it is from abandoning combustion engines and other fossil fuel burning technologies for the purposes of heating or transport. A strong renewable-based electrification of the economies is a condition for the fulfilment of targets regarding zero emissions. Another related feature is the total elimination of solid fossil fuels, oil and gas from the portfolio of primary energy sources. Nevertheless, such progress is quite dependent on technological solutions that are not yet totally available, for example in what concerns the storage of large amounts of energy.

The debate on energy and climate action is also inexorably linked to energy intensity. The ability to generate value-added with the smallest energy consumption possible is also key to meet the internationally agreed targets for greenhouse gas reductions. Energy intensity depends on the climatic conditions of countries and also on the type of technology used and the organization of production.

In this article we try to contribute to these debates by computing a set of energy-related indicators for Portugal and the Euro area in the period 1990-2019. This long time span makes it possible to gauge the pace of transition towards a scenario where fossil fuels are absent from the portfolio of primary energy sources and renewable energies prevail. In parallel, it is important to assess gains in terms of energy intensity, i.e., lower amounts of energy used for each unit of value-added produced in the economy, in industries and in individual firms. In the aggregate analysis, in order to set useful benchmarks, we compare domestic aggregate and industry-level energy intensities with those of the euro area.

A novel element in this article is the use of detailed firm-level data regarding expenditure in electricity and liquid fuels. The firm-level analysis discloses strong heterogeneity across firms in terms of nominal energy mix and intensity, a feature common to numerous other firm-level characteristics. In addition, the granular information provided by firm-level data provides insights for targeted economic policies. The "European Green Deal" targets a 55 per cent reduction in carbon emissions in the EU compared to 1990 levels by 2030, and aims the block to become carbon-neutral by 2050. Meeting these goals will forcefully imply policies targeted at energy adaptation, which may have a different impact depending on firms' characteristics. Firms' size is a very important dimension of analysis as energy-related technologies may be dependent on scale, both in terms of their technical feasibility and investments' rates of return. It is also worth noting that EU internal restrictive policies prompt the relocation of production to countries with lower carbon prices and softer legislation, which links with the proposal for a EU Carbon Border Adjustment Mechanism (CBAM), currently under discussion.

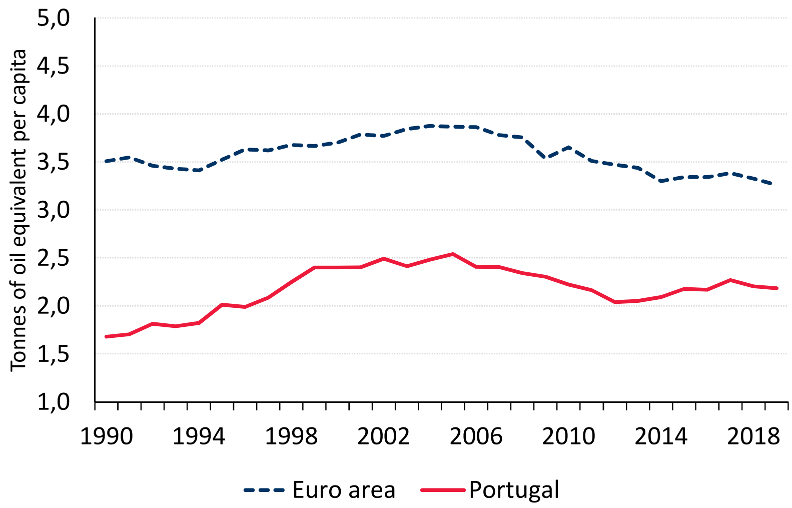


FIGURE 1: Energy consumption per capita

Notes: Author's calculations based on Eurostat energy balances and European Commission AMECO database.

The consumption of energy per capita in Portugal is lower than in the euro area (Figure 1). Nevertheless, total consumption of energy in Portugal increased by 34 per cent since 1990, which compares with a 2 per cent increase in the euro area in the same period. The rise in total consumption was extremely strong until the mid-2000s but it decreased until 2012 and broadly stabilized afterwards. A milder but qualitatively similar path was observed in the euro area. Overall energy consumption levels and developments depend on several important features that are identified in the article.

Portugal has made progress regarding the share of renewables and biodiesel, which represent close to a third of total energy consumption. The share of these primary energy sources in the euro area is smaller than in Portugal (about 16 per cent in 2019). Nevertheless, the Portuguese energy dependence remains substantially higher than that of the euro area, which poses challenges in terms of exposure to external shocks. As for energy intensity, Portugal has made substantial progress since the mid-2000s but gains in the euro area have started earlier and been steadier. As for the results derived from individual data on energy expenditure, there is strong heterogeneity across firms. The distribution of energy expenditure on total value added resembles a Pareto distribution and that of the share of electricity on total energy expenditure is bimodal in the tails. The correlation between firms' energy intensity and their size, measured either in terms of total turnover or employment, is negative. The negative correlation between firms' electricity share and size is not so strong. In addition, there is evidence that a higher share of electricity in total energy expenditure is negatively correlated with the energy intensity in the firms.

The article is organized as follows. In the next section we briefly review the literature on energy consumption in Portugal and in an international perspective. Section 3 provides information on the three databases used in the analysis. Section 4 presents the path of energy dependence, energy intensity and energy mix at the aggregate and sectoral levels, always taking the euro area as a benchmark for the Portuguese situation. Section 5 uses firm-level data on yearly expenditures in energy items, GVA, turnover and employment to assess the energy intensity, electricity share and the relationship between these indicators and firms size. Finally, section 6 offers some concluding remarks.

2. Literature

The literature on energy mix and energy intensity is vast and such a survey is totally beyond the scope of this article. Nevertheless, we make brief reference to studies that relate with our work and that may be of interest to the reader.

Energy efficiency has been an important topic in EU energy policy and this has materialized in specific legislation. The first Directive on energy efficiency dates back to 2006 (The European Commission (2006)) and a revision is presently under discussion (The European Commission (2021)). From an academic perspective, the analysis of energy efficiency in the EU, with an emphasis on Italian and UK regulatory experiences, was studied in Malinauskaite *et al.* (2019).

Beyond the EU, other international organizations regularly trace cross-country developments in energy policies and in the main variables of interest. Examples of yearly analysis are OECD (2020), IEA (2021b) and IEA (2021a). In the same vein, Kaivo-oja *et al.* (2016) studies trends in electricity production and consumption in China, US, the Euro area and the EU in the period 1961–2011 using World Bank and IEA data. Energy intensity analysis, which requires information on value added, is mostly studied at a very aggregate level. Geller *et al.* (2006) reviews energy intensity trends for Japan, United States, and Western Europe since 1973, also considering the role of structural change.

As for Portugal, studies focusing on the path of the main energy variables are also scarce. Nunes (2018) takes a secular perspective on energy developments up to the mid-2000s, while Amador (2010) follows a similar approach analysing the period the period 1960-2008 and comparing Portugal with other European countries. Other contributions based on the Portuguese experience lay on the frontier between energy and environmental issues, often linking with the evaluation of the impacts of policies. Examples are Pereira and Pereira (2019) and Alves *et al.* (2010).

As for the analysis of energy issues at the firm level, the literature is quite scarce. One thoughtful contribution is Zhang *et al.* (2016), which uses a firm-level data envelopment analysis to study energy efficiency in the Swedish industry. In addition, the paper delves into causality to assess how the EU ETS, the carbon dioxide tax and the energy tax affect energy efficiency. Another recent contribution is Lee and Yu (2019), which uses a time-series panel vector model to analyse the interdependencies between energy usage, costs, the share of renewable, economic growth, and greenhouse gas emissions in the Korean industrial sector, with an emphasis on firms' size.

3. Data

This article combines analysis with aggregate and firm-level dimensions, which are not fully integrated due the different nature of the underlying data. The aggregate dimension uses energy data in real terms, i.e., measured in tonnes of oil equivalent (TOE), as well as gross value added (GVA) at constant prices for the overall economy, main sectors and selected manufacturing industries. The firm-level analysis is based in nominal values and corresponds to energy-related expenditures, GVA, turnover and employment for virtually the universe of Portuguese firms.

Energy commodities are often bought for their heat-rising properties and can be converted into derived fuels. Therefore, energy supply and consumption are expressed in specific units (terajoules or TOE) and the structure adopted to report the data is termed as "energy balance". This balance identifies the primary energy sources, breaks down its transformation into secondary energy sources and by the different sectors that consume them, all of it at a quite detailed level in terms of energy types. This allows us to assess the relative importance of the different fuels in terms of their contribution to energy production and consumption. In this article we use the detailed energy balances available online at the Eurostat webpage, covering all EU individual Member-states, the EU and euro area aggregates for the period 1990-2019.

The data on GVA at constant prices was collected from the 2019 release of the EU Klems database run by the Vienna Institute for International Economic Studies (wiiw). The database provides measures of economic growth, productivity, employment, capital formation, and technological change at the industry level for all EU member states, Japan and the US in the period 1995-2017. An overview of data construction issues and methodology is thoroughly presented in Stehrer *et al.* (2019).

The third database used in this article collects detailed balance sheet and income statement information for virtually the universe of Portuguese firms, including sole proprietorships, for the period 2011-2018. The "*Sistema de contas integradas das empresas*" is maintained by Statistics Portugal and derives from firms mandatory reporting to tax and social security authorities as well as the legal obligation to submit their balance sheets. Beyond detailed information regarding expenditure on electricity and liquid fuels, this dataset contains a large number of balance sheet and income statement variables, which allow us to identify firms' characteristics. The non-energy variables used in the article comprise turnover, employment and GVA.

4. Aggregate analysis

This section presents the path of basic energy indicators for Portugal and the euro area since the nineties. The indicators concern energy dependence, energy intensity, detailing along main sectors and industries, and energy mix.

4.1. Energy dependence

The energy dependence ratio concerns the proportion of energy that an economy must import. In this article we define it as net energy imports (imports minus exports) divided by total energy supply minus changes in stocks, expressed as a percentage. A negative dependence ratio indicates a net exporter of energy, while a dependence rate in excess of 100 per cent indicates that energy products have been stocked.

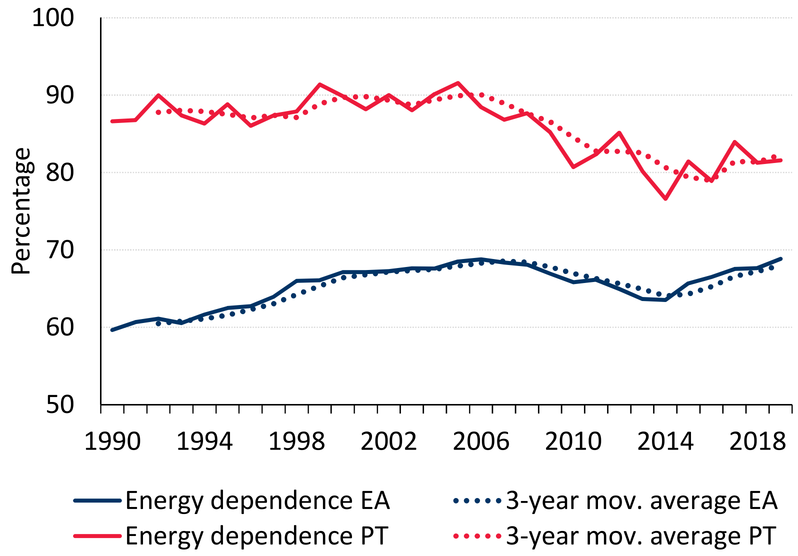


FIGURE 2: Energy dependence

Notes: Authors' calculations based on Eurostat energy balances

Figure 2 presents the energy dependence ratio from 1990 to 2019 in Portugal and the euro area. The figure also reports the 3-year moving average of the indicator in order to smooth out the impact of changes in stocks. Portugal posts a higher energy dependence ratio than the euro area. In the period 2017-2019, the ratio stood at values slightly higher than 80 per cent, after having decreased from values close to 90 per cent in the mid 2000s. In the euro area the ratio has been increasing since 2014 to values close to 70 per cent in 2019.

It is important to note that, although highly relevant, the dependence ratio does not provide full information about energy security, interpreted as the reliability of energy supply. The diversification of foreign energy suppliers, as well as their geographical positioning and political stability are also very important variables when it comes to reduce the exposure to the risk of supply shortages motivated by public health or political crises, conflict or natural disasters. In any case, since the endowment of primary energy sources roots on countries' natural conditions, international trade of energy goods is essential.

4.2. *Energy intensity*

Energy intensity is typically expressed in kilotons of oil equivalent (Ktoe) per unit of GVA taken at constant prices. It is important to note that energy intensity does not necessarily reflect energy efficiency, as the latter also depends on elements that are not taken into account by the simple measure of energy supply to GVA (e.g., climate and sectoral structure of the economy). Filippini and Hunt (2011) uses a parametric stochastic frontier analysis to obtain an energy demand function for 29 OECD countries over the period 1978 to 2006 and shows the differences between these two concepts. Nevertheless, the energy intensity indicator is very important to identify overall trends linking economic activity and energy use.

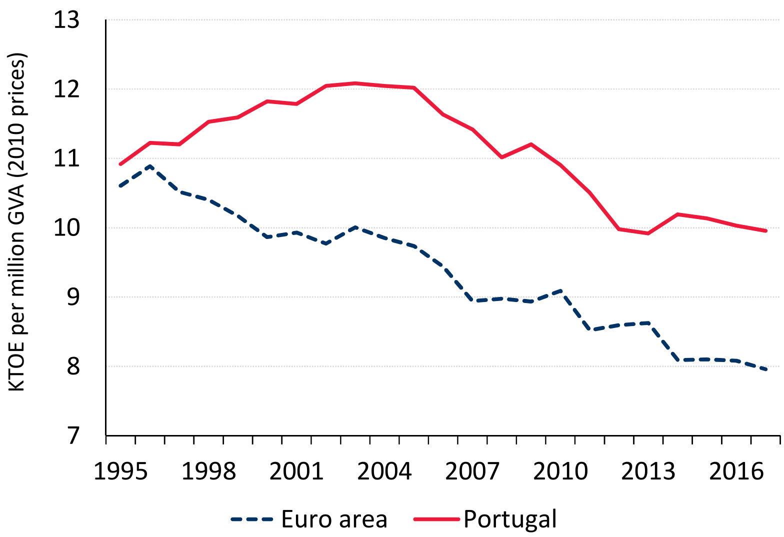
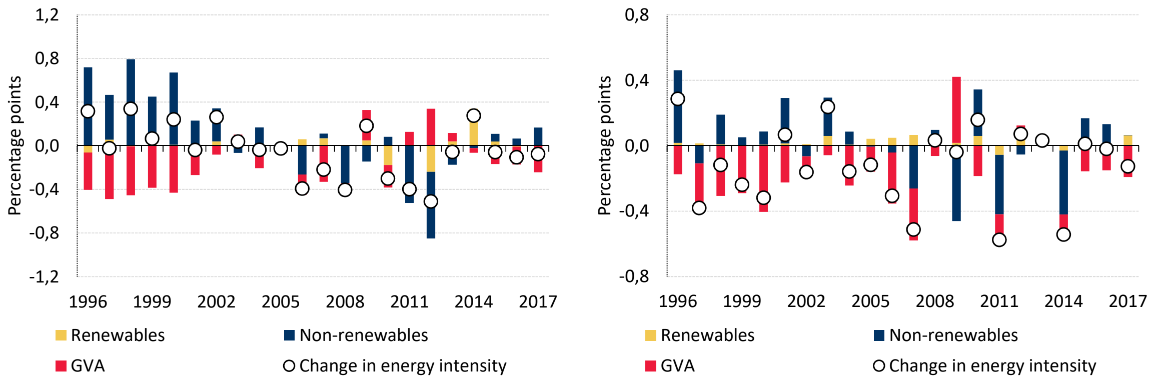


FIGURE 3: Energy intensity

Notes: Authors' calculations based on Eurostat energy balances and EU Klems database.

Figure 3 compares the level of energy intensity in Portugal and the euro area between 1995 and 2017. The level of the indicator was close in both regions in 1995 and developments have been quite positive, even if improvements only started in Portugal in the mid-2000s. From 1996 up to 2017 the accumulated reduction of Ktoe per million euro reached 9 and 25 per cent in Portugal and the euro area, respectively. Nevertheless, in Portugal this indicator increased by 10 per cent between 1996 and 2005. The yearly change in energy intensity can be broken down along the contributions of GVA growth and energy consumption, and also in terms of its renewable and non-renewable components. The panels of Figure 4 present this basic decomposition in Portugal and the euro area. The contribution of GVA developments (the denominator effect) is typically very important to explain yearly changes in the indicator, while the contribution of renewables is not. Since energy is an important input for production, its consumption is positively correlated with activity. Therefore, the contribution of energy consumption has typically the opposite sign of the GVA. This pattern was affected by the sovereign debt crisis in the euro area and by the Portuguese 2011-2014 economic



(A) Portugal (B) Euro area

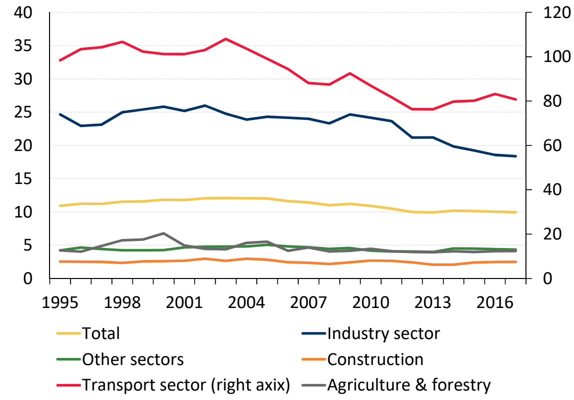
FIGURE 4: Decomposition of change in energy intensity

Notes: Authors' calculations based on Eurostat energy balances and EU Klems database.

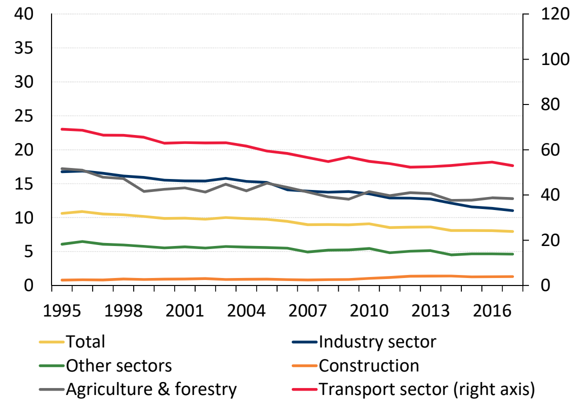
and financial assistance program, as well as by progress in energy efficiency in the two economies.

It is relevant to compare energy intensity levels and developments across the main economic sectors. The two panels of Figure 5 present values for Portugal and the euro area and make it clear that "transportation" is, by far, the most energy intensive sector. The level of the indicator in 2017 in this sector is 53 per cent higher in Portugal than in the euro area. The other energy intensive sectors are "industry" and, in the euro area, "agriculture and forestry". If we detail the manufacturing sector the "chemicals and petrochemicals" and "paper, pulp and printing" are the most energy intensive industries both in Portugal and in the euro area (Figure 6). These unsurprising results accrue to the specific nature of these activities, where energy saving technologies would bring important gains.

The two panels of Figure 7 compare energy intensity in 1995 and 2017 in Portugal and in the euro area, while signalling the relative importance of each main sector in energy consumption in 2019. The figure highlights the importance of the transport sector as a user of energy in both economies (36.6 and 31.3 per cent in Portugal and in the euro area, respectively) and also the existence of important progress in Portugal in period considered. The share of industry in energy consumption is smaller (27.3 and 24.3 per cent in Portugal and the euro area, respectively) and also smaller than in "other sectors", which includes "commercial and public services" and "households". In the same vein, the two panels of Figure 8 compare energy intensity in 1995 and 2017 in Portugal and the euro area in selected manufacturing sectors. In the case of the euro area the share of manufacturing sectors on energy consumption is more evenly distributed than in Portugal, where "paper, pulp and printing" stands out, and represents about 9 per cent of total energy consumption.

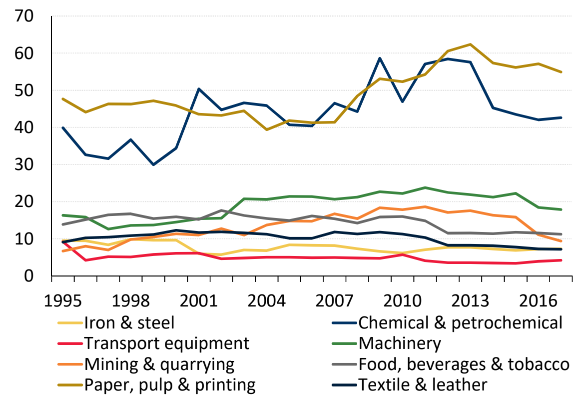


(A) Portugal

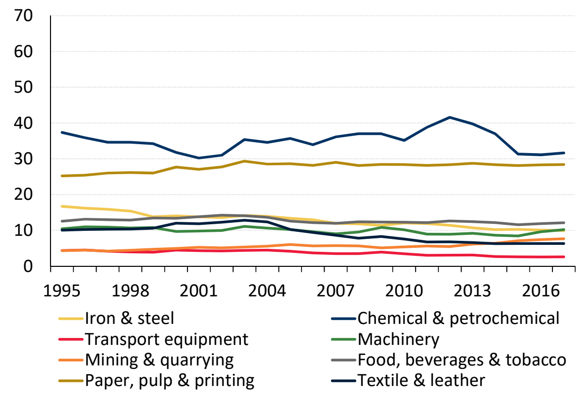


(B) Euro area

FIGURE 5: Energy intensity in main sectors (Ktoe per million GVA at 2010 prices)

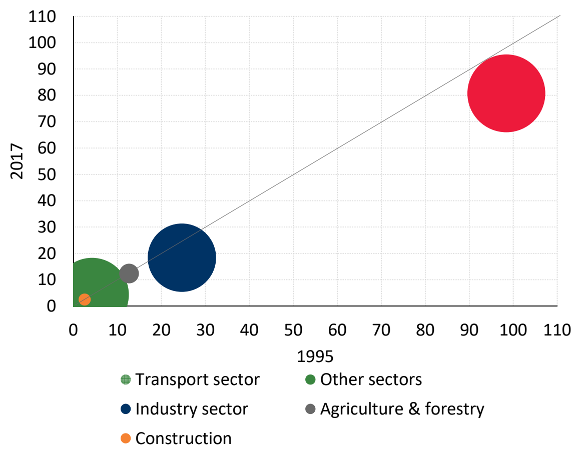


(A) Portugal

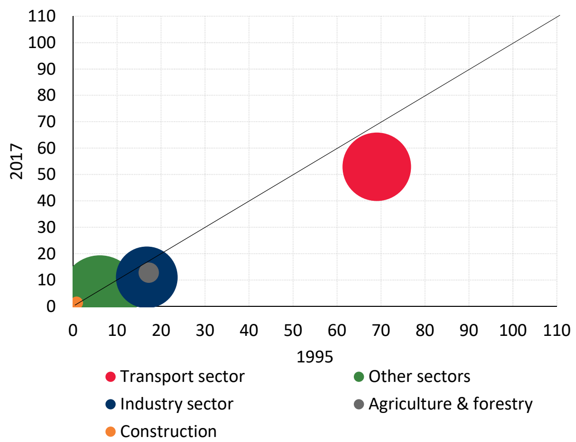


(B) Euro area

FIGURE 6: Energy intensity in main manufacturing industries (Ktoe per million GVA at 2010 prices)



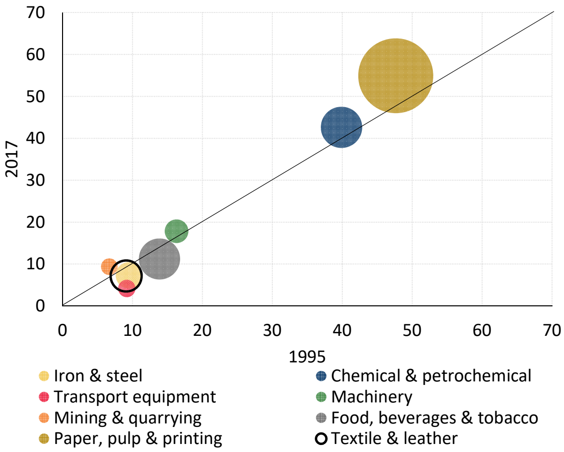
(A) Portugal



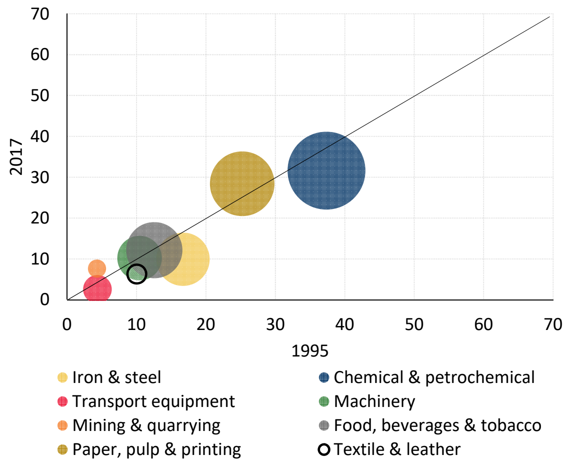
(B) Euro area

FIGURE 7: Energy intensity: 1995 vs 2017 - Main sectors (Ktoe per million GVA at 2010 prices)

Note: The diameter of the circles is proportional to the importance of sector in total energy consumption in 2019.



(A) Portugal



(B) Euro area

FIGURE 8: Energy intensity: 1995 vs 2017 - Manufacturing (Ktoe per million GVA at 2010 prices)

Note: The diameter of the circles is proportional to the importance of each manufacturing sector in total energy consumption in 2019.

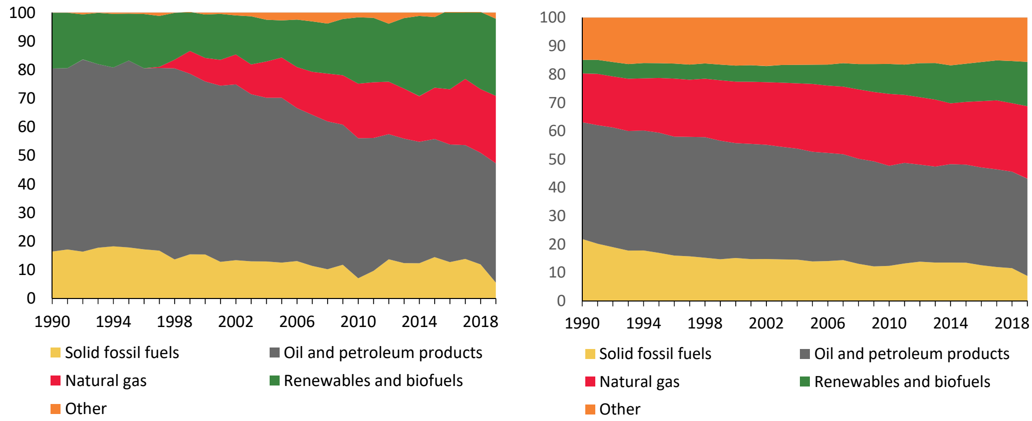
4.3. *Energy mix*

The energy supply mix is the structure of energy supply in terms of primary energy source as a percentage of total energy supply in the country. A key dimension of interest, in connection with climate challenges, is the share of renewables in the energy supply mix and in the production of electricity, i.e, the role of hydro, geothermal, wind, biomass, waste and solar energy.

The two panels of Figure 9 present the energy supply mix in Portugal and the euro area in the period 1990-2019. The most relevant features in Portugal are the rise of natural gas as a primary energy source in the late nineties, reaching nearly one fourth of total energy supply in 2019, and the steady increase in the share of renewables and biofuels since 2000, reaching 27 per cent in 2019. In contrast, in the euro area there is a much lower share of renewables (about 16 per cent in 2019) and a larger share of "Other" category. The latter difference accrues to the share of nuclear energy, which accounted for about 15 per cent ot total energy supply in the euro area in 2019.

The two panels of Figure 10 detail the share of different primary renewable energy sources in Portugal and the euro area. Except for the larger share of solar energy in the euro area, differences in this structure are not striking in the latest years. One difference is the higher volatility in the share of hydro energy in Portugal, which can be easily understood by the uneven yearly rain patterns, which are averaged out in the larger euro area aggregate.

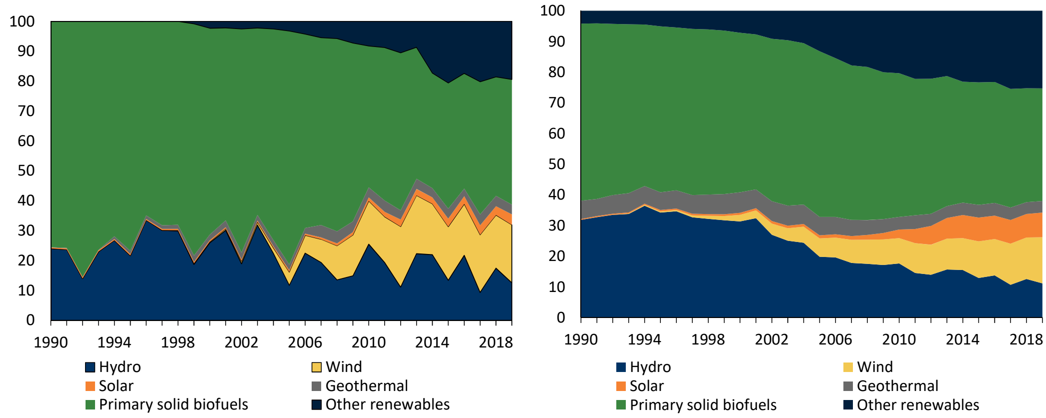
The primary energy mix documented above is transformed into secondary energy sources that are consumed by households and firms. As previously mentioned, it is particularly important to quantify the share of electricity on total energy consumption and its primary energy sources. Indeed, carbon neutrality is expected to be achieved through a renewable-based electrified economy. Figure 11 presents the share of



(A) Portugal (B) Euro area

FIGURE 9: Energy mix in Portugal and in the Euro area

Sources: Eurostat energy balances and author's calculations.
Note: The category "Other" in the graph is mostly composed by nuclear energy.



(A) Portugal (B) Euro area

FIGURE 10: Renewables mix in Portugal and in the Euro area

Sources: Eurostat energy balances and author's calculations.

electricity in total energy consumption in Portugal and in the euro area in the period 1990-2019. This figure shows an upward trend in this share in both regions, but electricity represents only about one-quarter of total energy consumption.

The two panels of Figure 12 present the breakdown of electricity consumption along the different primary energy sources that generate it, both in Portugal and in the euro area. An important result is the still limited share of electricity derived from renewable sources, especially in the euro area. In Portugal this share was 40 per cent in 2019, while in the euro area it was only 22 per cent. Nevertheless, the strong role of nuclear energy as a source of electricity in the euro area must be highlighted (36 per cent in 2019). Although beyond the period under analysis in this article, it is worth remarking the elimination of coal to produce electricity in Portugal in 2021.

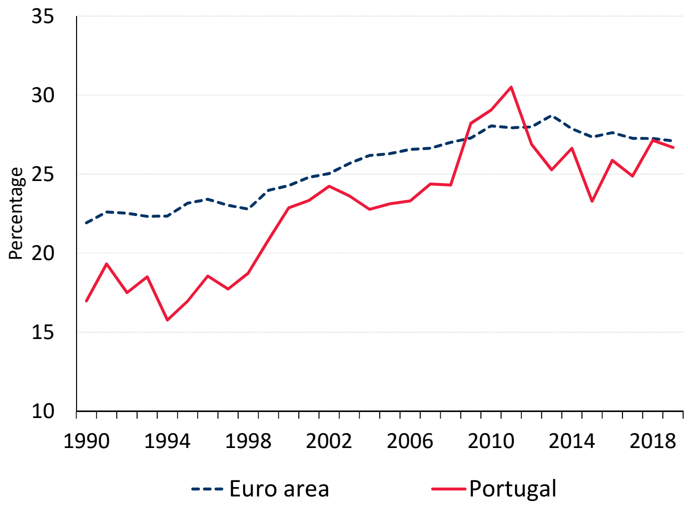
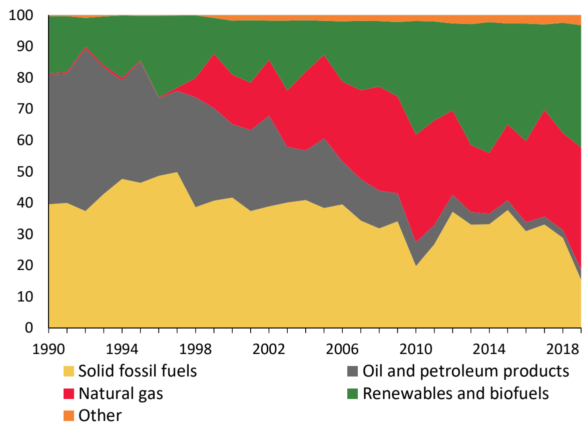
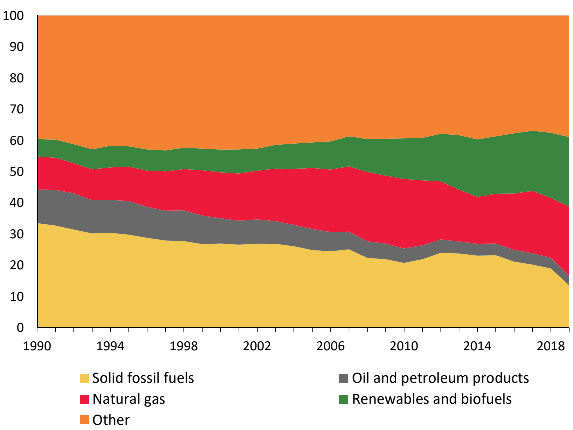


FIGURE 11: Share of electricity in energy consumption

Notes: Authors' calculations based on Eurostat energy balances



(A) Portugal



(B) Euro area

FIGURE 12: Breakdown of electricity consumption by primary sources that generate it in Portugal and in the euro area

Sources: Eurostat energy balances and author's calculations.
Note: The category "Other" in the graph is mostly composed by nuclear energy.

5. Firm-level analysis

In the second part of the article we turn to firm-level data on yearly electricity and liquid fuels expenditures to complement the portrait obtained from aggregate energy data and GVA. A limitation of this type of data is the fact that they are expressed in nominal terms, thus combining energy prices and quantities consumed. Firm-level data on energy consumed in real terms is only available for a sample of larger manufacturing firms, thus not sufficiently describing the landscape of firms in the economy.

Although focusing strictly on quantities of energy consumed would be preferable, the analysis of expenditure data is useful and interpretable. Moreover, if the analysis is conducted in terms of ratios, where prices affect both numerator and denominator, comparisons between firms and density distributions convey relevant information. The fluctuation of prices along time can be overcome by focusing on a cross section of a specific year or by adding time fixed effects in the context of a regression. Another element that may confound the results is the possibility of having different energy prices for firms of different sizes. In theory, large consumers may bargain lower prices from their energy suppliers or public policies may distort energy prices faced by firms of different sizes due to subsidization or taxation rules. In order to overcome this potential difficulty, we detail results for the subset of micro, small, medium and large firms in our sample, classified along the definition used by the European Commission.[1] As a standard cleaning procedure, we eliminate all observations in the database with negative GVA, turnover or expenditures with goods and services.

5.1. Energy intensity of firms

Figure 13 plots the non-weighted kernel distribution of the ratio of energy expenditures on GVA for all firms in the sample in 2018, truncated at the 1st and 99th percentiles. This ratio informs on the energy intensity of firms. The distribution is strongly right skewed, with a large density of firms with low energy expenditures on total GVA and a small number of them with very large values. This Pareto-like distribution is associated with the sectoral specificities of firms' activity. In this vein, Figure 14 ranks NACE 2-digit sectors from the highest to the lowest in terms of the average of the ratio of total energy expenditure on GVA in 2018. Results show again important differences across sectors, with "land transport" posting a ratio of 78 per cent, in contrast with "employment activities" and "tobacco" with average ratios lower than 5 per cent. If the ranking is constructed basing on the median of the ratio in the sector, results are broadly unaltered. The 2-digit level values for the mean, median and interquartile range are presented in Table A.1 in the Appendix.

Firms' size is a very important dimension of analysis as specific energy-related technologies may be dependent on scale, both in terms of technical feasibility and return. The relationship between firms size and energy consumption patterns is also relevant for the correct design of public policies. Therefore, we statistically assess the correlation between the energy intensity and the size of firms, measured either by the logarithm of total turnover or employment, while bearing in mind the sectoral heterogeneity and the problems that emerge from dealing with effects associated to different prices by larger consumers versus smaller ones. These concerns are addressed by considering firm and time fixed effects and separate regressions for firms in different size categories.

1. According to the Recommendation of the European Commission 2003/361/EC, the category of micro-sized firms includes those that employ fewer than 10 workers and have an annual turnover or total annual balance sheet not in excess of 2 million euros. In turn, small firms employ fewer than 50 workers and have an annual turnover or total annual balance sheet not in excess of 10 million euros. The medium-sized firms employ fewer than 250 workers and have an annual turnover not in excess of 50 million euros or a total annual balance sheet not in excess of 43 million euros. Large firms are those that do not belong to any of the aforementioned categories.

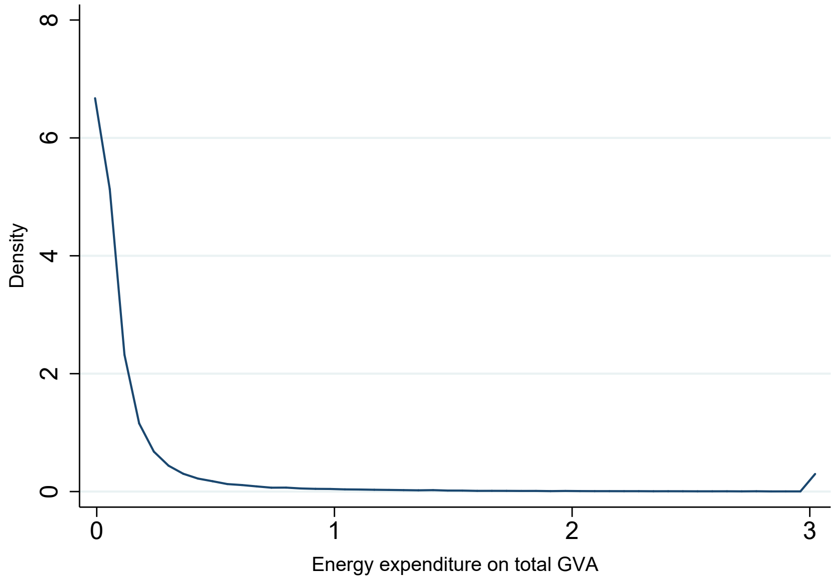


FIGURE 13: Energy expenditure on total GVA in 2018

Notes: Energy expenditure comprises electricity and liquid fuels. Non-weighted observations.

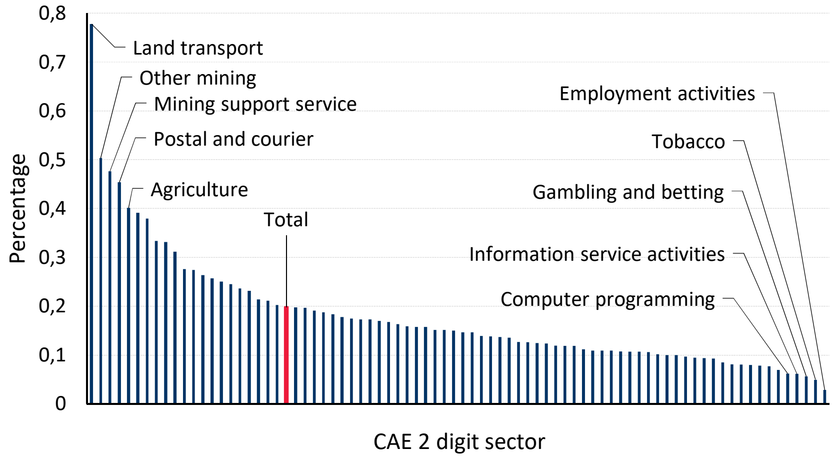


FIGURE 14: Average share of energy expenditure on total GVA across sectors in 2018

Moreover, the inclusion of firm fixed effects in regressions will capture other time invariant firms' characteristics that may affect their energy consumption patterns.

It could be argued that exploring variability across firms in each sector would be the easiest approach to establish a link between the ratio of energy expenditures on GVA and the size of firms. This would imply running regressions with sectoral fixed effects instead of firm fixed effects. However, the heterogeneity of activities within sectors is still quite large (e.g., in agriculture, greenhouse flowers differ from extensive olive oil production) and other firms' characteristics (e.g. power and reliability of the electric grid where it is located) advise for considering firm fixed effects.

Table 1 presents estimated coefficients for the semi-elasticity between the ratio of energy expenditures on GVA and the logarithm of turnover in the period 2011-2018, which are consistently negative and statistically significant, meaning that larger firms post a lower energy expenditure for each euro of GVA generated, i.e., they are less energy intensive. Table 2 repeats the exercise above, taking the logarithm labour as the proxy for size and results are quite consistent, except for the class of large firms where the coefficient turns out non significant.

VARIABLES	(1) Total	(2) Micro	(3) Small	(4) Medium	(5) Large
ln turnover	-0.051***	-0.055***	-0.047***	-0.031***	-0.015***
	(0.001)	(0.001)	(0.002)	(0.004)	(0.005)
Constant	0.796***	0.837***	0.790***	0.601***	0.352***
	(0.007)	(0.007)	(0.028)	(0.063)	(0.091)
Observations	2,184,001	1,819,364	282,101	48,396	9,208
Adjusted R^2	0.507	0.493	0.691	0.672	0.689
Time FE	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

TABLE 1. Energy intensity and size of firms measured by turnover

Notes: The dependent variable corresponds to the ratio of total energy expenditures (electricity plus liquid fuels) on firms' GVA. Significances are computed using robust clustered errors.

VARIABLES	(1) Total	(2) Micro	(3) Small	(4) Medium	(5) Large
ln nb. employees	-0.040***	-0.045***	-0.031***	-0.018***	-0.006
	(0.001)	(0.001)	(0.002)	(0.006)	(0.005)
Constant	0.242***	0.243***	0.221***	0.191***	0.128***
	(0.001)	(0.001)	(0.006)	(0.025)	(0.031)
Observations	2,184,001	1,819,364	282,101	48,396	9,208
Adjusted R^2	0.504	0.489	0.689	0.671	0.688
Time FE	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

TABLE 2. Energy intensity and size of firms measured by employment

Notes: The dependent variable corresponds to the ratio of total energy expenditures (electricity plus liquid fuels) on firms' GVA. Significances are computed using robust clustered errors.

5.2. *Energy mix of firms*

Figure 15 plots the non-weighted kernel distribution of the share of electricity on total energy expenditure for all firms in the sample in 2018. This ratio proxies the energy mix of firms. The distribution is bimodal, with a larger density of firms that use little electricity on their activity and on firms that use almost exclusively this energy item. This pattern results from firms technological decisions and the specific nature of their business. For example, even if electric vehicles are available, transportation firms spend almost exclusively on liquid fuels, while services firms spend almost exclusively on electricity. As expected, many firms combine both types of energy expenditures. The possibility of considering other types of energy expenditure or energy self-production in the denominator was abandoned due to the lack of data.

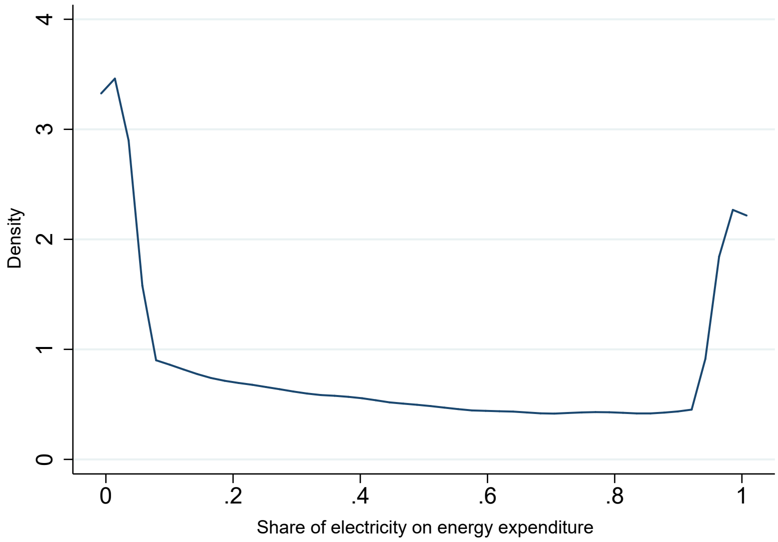


FIGURE 15: Share of electricity on total energy expenditure in 2018

Notes: Total energy expenditure comprises electricity and liquid fuels expenditure. Non-weighted observations.

In Figure 16, using a NACE 2-digit classification, sectors are ranked from the highest to the lowest in terms of the average of the ratio of electricity on total energy expenditure in 2018. Results show important differences across sectors, with “land transport” and “postal and courier” posting ratios lower than 7 per cent, in strike contrast with “food and beverages services”, “electricity and gas” and “accommodation” with average ratios higher than 70 per cent. The detailed 2-digit level values for the mean, median and interquartile range are presented in Table A.1 in the Appendix.

At this point we turn to testing the association between the share of electricity expenditure on total energy expenditure (electricity and liquid fuels) and firm size, proxied both by the logarithm of turnover and employment, while controlling for time and firm specific effects. Table 3 reports the results of the regression, considering the overall sample of firms and subsamples for the four categories of firms in the period 2011-2018. Results are not as strong as those obtained for the association between energy intensity and size. Estimated coefficients for the semi-elasticities are negative and significant only for the overall sample and for the sets of micro and small firms.

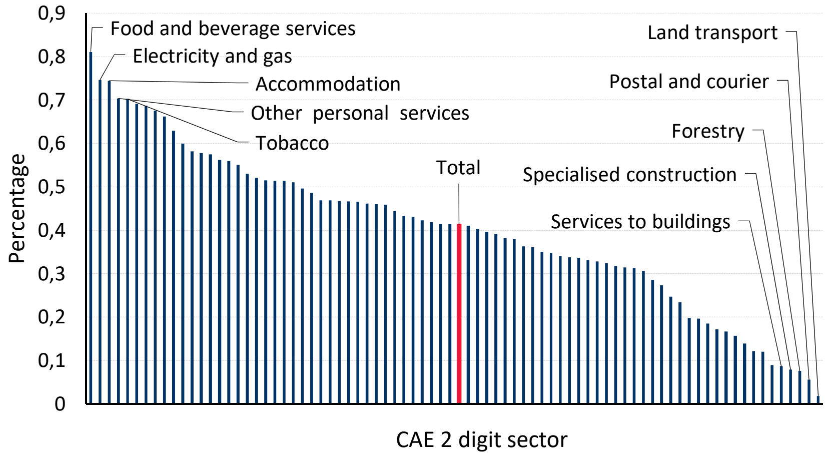


FIGURE 16: Average share of electricity on total energy expenditure across sectors

VARIABLES	(1) Total	(2) Micro	(3) Small	(4) Medium	(5) Large
ln turnover	-0.016***	-0.017***	-0.012***	-0.002	-0.008
	(0.000)	(0.000)	(0.001)	(0.003)	(0.007)
Constant	0.607***	0.607***	0.593***	0.539***	0.682***
	(0.004)	(0.005)	(0.017)	(0.052)	(0.121)
Observations	1,902,385	1,548,971	274,230	47,206	8,995
Adjusted R^2	0.860	0.856	0.907	0.924	0.925
Time FE	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

TABLE 3. Share of electricity on total energy expenditure and size of firms measured by turnover

Notes: The dependent variable corresponds to the ratio of total energy expenditures (electricity plus liquid fuels) on firms' GVA. Significances are computed using robust clustered errors.

Table 4 repeats the previous exercise considering the logarithm of the number of employees as the indicator of size, instead of total turnover. Results are consistent with those obtained above. The coefficient of size, proxied by the logarithm of employment, in the overall sample is negative and significant and the same result exists for the subsample of micro firms. Nevertheless, coefficients for small, medium and large firms are not statistically different from zero.

VARIABLES	(1) Total	(2) Micro	(3) Small	(4) Medium	(5) Large
ln nb. employees	-0.010***	-0.012***	-0.002	0.007	0.014
	(0.000)	(0.001)	(0.002)	(0.004)	(0.009)
Constant	0.425***	0.416***	0.430***	0.475***	0.465***
	(0.001)	(0.001)	(0.004)	(0.017)	(0.051)
Observations	1,902,385	1,548,971	274,230	47,206	8,995
Adjusted R^2	0.860	0.855	0.907	0.924	0.925
Time FE	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

TABLE 4. Share of electricity on total energy expenditure and size of firms measured by employment

Notes: The dependent variable corresponds to the ratio of total energy expenditures (electricity plus liquid fuels) on firms' GVA. Significances are computed using robust clustered errors.

5.3. *Correlation between firms energy intensity and the share of electricity*

As previously stated, lower energy intensity and a higher share of electricity in total energy consumption are desirable. High electrification would open the door to satisfy firms energy needs through renewable energy sources, while a lower energy intensity would prompt the economy to lower overall energy consumption. In this vein, we explicitly test the correlation between these two variables, while controlling for time and sector specific effects.

VARIABLES	(1) Total	(2) Micro	(3) Small	(4) Medium	(5) Large
Electricity share	-0.045***	-0.044***	-0.020***	-0.020***	-0.077***
	(0.001)	(0.001)	(0.002)	(0.004)	(0.009)
Constant	0.246***	0.265***	0.151***	0.127***	0.136***
	(0.000)	(0.001)	(0.001)	(0.002)	(0.006)
Observations	1,974,701	1,624,935	290,766	49,707	9,290
Adjusted R^2	0.134	0.126	0.289	0.235	0.240
Time FE	YES	YES	YES	YES	YES
Sector FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

TABLE 5. Correlation between firms' energy intensity and the share of electricity in total energy expenditure

The dependent variable corresponds to the ratio of total energy expenditures on firms' GVA and the explanatory variable "electricity share" stands for the share of electricity on total energy expenditure. Significances are computed using robust clustered errors at the firm level.

Table 5 presents the coefficients of a regression where the independent variable is the share of electricity expenditures on total energy expenditure and the dependent variable is the ratio of energy expenditure on firm's GVA. The coefficients are negative and strongly significant for the overall sample and for the four different firm size classes taken separately. This result signals that underperformance in these two dimensions goes hand in hand in most firms.

6. Final remarks

The challenges posed by climate change and the need to meet the calendars established for carbon neutrality are extremely ambitious. Therefore, the adjustment effort required by economic agents is very large. From an aggregate perspective, this involves increasing the share of renewables in total primary energy, as well as reducing the amount of energy consumed for each unit of value added created in the economy. We identify progress in Portugal and in the euro area in both dimensions. Nevertheless, the pace of transformation should be increased if targets are to be met.

Policy action at firm level is particularly challenging and needs to informed by empirical micro-based evidence. Although we do not have real energy consumption data for firms, energy expenditure data provides some initial insights. We document substantial heterogeneity at the sectoral and firm size dimensions. The goal of lower energy intensity seems to be facilitated by having larger firms, but this is not so clear for the purpose of increasing electrification. Nevertheless, underperformance in these two dimensions seems to go hand in hand in most firms.

There is large room to proceed with this research agenda, notably in the firm-level dimension and especially in the link between energy consumption patterns and firms' size. One natural extension is to test causality between firms' size and both their energy mix and energy intensity ratio, i.e., going beyond simple correlations, as tested in this article. In turn, establishing a link between energy intensity and labour productivity seems problematic as GVA is present in the denominator of both dependent and independent variables. However, a focus on total factor productivity may bear interesting results. Moreover, assessing the role of international trade and digitalization in connection to firms' energy consumption patterns are also interesting research questions. Finally, mapping the impact of energy consumption patterns on emissions is highly relevant in what concerns the climate agenda.

References

Alves, M., M. Rodríguez, and C. Roseta-Palma (2010). "Sectoral and regional impacts of the European Carbon Market in Portugal." Working Paper 21, GEE.

Amador, João (2010). "Energy Production and Consumption in Portugal: Stylized Facts." *Economic Bulletin Articles of Banco de Portugal*.

Filippini, Massimo and Lester Hunt (2011). "Energy Demand and Energy Efficiency in the OECD Countries: A Stochastic Demand Frontier Approach." *The Energy Journal*, 32, 59–80.

Geller, Howard, Philip Harrington, Arthur H. Rosenfeld, Satoshi Tanishima, and Fridtjof Unander (2006). "Polices for increasing energy efficiency: Thirty years of experience in OECD countries." *Energy Policy*, 34(5), 556–573.

IEA (2021a). "Renewables 2021: Analysis and forecasts to 2026." Report, International Energy Agency.

IEA (2021b). "World Energy Outlook." Report, International Energy Agency.

Kaivo-oja, Jari, Jarmo Vehmas, and Jyrki Luukkanen (2016). "Trend analysis of energy and climate policy environment: Comparative electricity production and consumption benchmark analyses of China, Euro area, European Union, and United States." *Renewable and Sustainable Energy Reviews*, 60, 464–474.

Lee, Jaeseok and Jongmin Yu (2019). "Heterogenous Energy Consumption Behavior by Firm Size: Evidence from Korean Environmental Regulations." *Sustainability*, 11-3226.

Malinauskaite, J., H. Jouhara, L. Ahmad, M. Milani, L. Montorsi, and M. Venturelli (2019). "Energy efficiency in industry: EU and national policies in Italy and the UK." *Energy*, 172, 255–269.

Nunes, Adélia (2018). "Energy changes in Portugal: An Overview of the Last Century." *Méditeranée*, 130-2018.

OECD (2020). "Environment at a Glance." Report, Organization for Economic Cooperation and Development.

Pereira, R. and A. Pereira (2019). "Financing a Renewable Energy Feed-in Tariff with a Tax on Carbon Dioxide Emissions: A Dynamic Multi-Sector General Equilibrium Analysis for Portugal." Working Paper 123, GEE.

Stehrer, R., A. Bykova, K. Jäger, O. Reiter, and M. Schwarzhappel (2019). "Industry level growth and productivity data with special focus on intangible assets." Statistical Report 8, wiiw.

The European Commission (2006). "Directive of the European Parliament and of the Council on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC." Tech. rep., Office of the United Nations High Commissioner for Human Rights.

The European Commission (2021). "Proposal for a Directive of the European Parliament and of the Council." Tech. rep., Office of the United Nations High Commissioner for Human Rights.

Zhang, Shanshan, Tommy Lundgren, and Wenchao Zhou (2016). "Energy efficiency in Swedish industry: A firm-level data envelopment analysis." *Energy Economics*, 55, 42–51.

Appendix

		Electricity share			Energy intensity		
Code	NACE 2-digit sector	Average	P50	IQR	Average	P50	IQR
1	Agriculture	0,34	0,28	0,54	0,40	0,18	0,36
2	Forestry	0,08	0,00	0,02	0,39	0,25	0,38
3	Fishing	0,09	0,00	0,03	0,38	0,19	0,30
7	Mining of metal ores	0,69	0,96	0,78	0,12	0,11	0,10
8	Other mining	0,31	0,22	0,48	0,50	0,34	0,47
9	Mining support service	0,17	0,00	0,38	0,48	0,09	0,62
10	Food	0,57	0,58	0,59	0,27	0,17	0,17
11	Beverages	0,47	0,47	0,49	0,18	0,08	0,11
12	Tobacco	0,70	0,70	0,12	0,05	0,04	0,05
13	Textiles	0,55	0,57	0,55	0,16	0,08	0,12
14	Wearing apparel	0,51	0,51	0,45	0,08	0,04	0,05
15	Leather and its products	0,52	0,57	0,41	0,08	0,04	0,05
16	Wood products, except furniture	0,43	0,43	0,45	0,20	0,10	0,14
17	Paper and its products	0,47	0,45	0,45	0,16	0,08	0,09
18	Printing and reproduction	0,51	0,51	0,46	0,11	0,07	0,07
19	Coke and refined petroleum	0,35	0,25	0,42	0,15	0,07	0,10
20	Manufacture of chemicals and its products	0,42	0,33	0,58	0,18	0,09	0,13
21	Pharmaceutical	0,46	0,51	0,71	0,08	0,04	0,06
22	Rubber and plastic	0,66	0,78	0,44	0,20	0,13	0,16
23	Other non-metallic mineral products	0,49	0,48	0,49	0,26	0,14	0,19
24	Basic metals	0,51	0,50	0,59	0,15	0,08	0,13
25	Metal products, except machinery and equipment	0,36	0,29	0,46	0,13	0,07	0,08
26	Computer, electronic and optical	0,47	0,42	0,76	0,11	0,04	0,07
27	Electrical equipment	0,40	0,34	0,46	0,12	0,06	0,08
28	Machinery and equipment n.e.c.	0,38	0,34	0,43	0,11	0,06	0,07
29	Motor vehicles, trailers and semi-trailers	0,58	0,60	0,51	0,11	0,05	0,06
30	Other transport equipment	0,46	0,42	0,60	0,10	0,05	0,08
31	Manufacture of furniture	0,50	0,50	0,49	0,15	0,09	0,09
32	Other manufacturing	0,47	0,42	0,54	0,10	0,05	0,07
33	Repair and installation of equipment	0,20	0,10	0,28	0,14	0,07	0,10
35	Electricity and gas	0,75	1,00	0,52	0,09	0,01	0,02
36	Water collection, treatment and supply	0,46	0,50	0,80	0,26	0,09	0,17
37	Sewerage	0,39	0,11	0,90	0,28	0,16	0,25
38	Waste collection, treatment and disposal	0,27	0,14	0,40	0,25	0,14	0,23
39	Remediation and other waste management	0,19	0,07	0,43	0,14	0,08	0,09
41	Construction of buildings	0,16	0,00	0,12	0,12	0,06	0,10
42	Civil engineering	0,12	0,02	0,09	0,19	0,09	0,17
43	Specialised construction	0,08	0,00	0,07	0,17	0,09	0,12
45	Trade and repair of motor vehicles and motorcycles	0,44	0,39	0,57	0,15	0,06	0,09
46	Wholesale trade, except vehicles and motorcycles	0,23	0,12	0,31	0,17	0,08	0,14
47	Retail trade, except vehicles and motorcycles	0,56	0,57	0,79	0,17	0,08	0,13
49	Land transport	0,02	0,00	0,00	0,78	0,49	0,74
50	Water transport	0,12	0,01	0,09	0,33	0,12	0,30

TABLE A.1. Distribution of the ratios: Electricity on total energy expenditure, and Energy expenditure on total GVA, for NACE 2-digit sectors, in 2018

Notes: p50 stands for the median and IQR stands for interquartile range.

		Electricity share			Energy intensity		
Code	NACE 2-digit sector	Average	P50	IQR	Average	P50	IQR
51	Air transport	0,34	0,08	0,65	0,24	0,01	0,18
52	Warehousing and support for transportation	0,33	0,17	0,60	0,19	0,04	0,13
53	Postal and courier	0,06	0,00	0,02	0,45	0,28	0,43
55	Accommodation	0,74	0,83	0,40	0,21	0,10	0,15
56	Food and beverage services	0,81	0,90	0,28	0,33	0,15	0,22
58	Publishing activities	0,38	0,26	0,69	0,08	0,02	0,06
59	Motion picture, video, TV and music	0,32	0,15	0,61	0,10	0,03	0,09
60	Programming and broadcasting	0,68	0,79	0,56	0,17	0,08	0,14
61	Telecommunications	0,20	0,00	0,17	0,15	0,07	0,15
62	Computer programming	0,32	0,17	0,53	0,06	0,01	0,05
63	Information service activities	0,41	0,26	0,92	0,06	0,01	0,05
68	Real estate activities	0,60	0,71	0,82	0,11	0,02	0,08
69	Legal and accounting activities	0,53	0,44	0,80	0,07	0,03	0,05
70	Head offices; management consultancy	0,35	0,17	0,73	0,08	0,01	0,06
71	Architectural and engineering activities	0,33	0,18	0,56	0,11	0,04	0,09
72	Scientific research and development	0,34	0,25	0,56	0,08	0,02	0,06
73	Advertising and market research	0,31	0,19	0,50	0,11	0,03	0,10
74	Other professional, scientific and technical act.	0,36	0,19	0,78	0,10	0,03	0,09
75	Veterinary activities	0,58	0,58	0,74	0,12	0,05	0,07
77	Rental and leasing activities	0,17	0,02	0,18	0,25	0,07	0,25
78	Employment activities	0,29	0,13	0,44	0,03	0,00	0,02
79	Travel agency and related activities	0,43	0,30	1,00	0,20	0,03	0,14
80	Security and investigation activities	0,14	0,07	0,14	0,12	0,06	0,11
81	Services to buildings	0,09	0,00	0,07	0,16	0,08	0,14
82	Office and other business support	0,31	0,12	0,59	0,14	0,04	0,12
85	Education	0,47	0,39	0,85	0,16	0,05	0,13
86	Human health activities	0,41	0,31	0,84	0,09	0,04	0,07
87	Residential care activities	0,63	0,65	0,46	0,09	0,06	0,06
88	Social work activities without accommodation	0,56	0,52	0,78	0,11	0,04	0,07
90	Creative, arts and entertainment activities	0,25	0,04	0,36	0,14	0,04	0,12
91	Cultural activities	0,42	0,30	0,82	0,13	0,06	0,11
92	Gambling and betting	0,69	0,84	0,63	0,06	0,03	0,05
93	Sports, amusement and recreation	0,41	0,23	0,92	0,31	0,11	0,29
94	Activities of membership organisations	0,51	0,55	0,21	0,23	0,08	0,18
95	Repair computers, personal and household goods	0,40	0,27	0,68	0,17	0,07	0,13
96	Other personal services	0,70	1,00	0,67	0,21	0,08	0,14
	All sectors	0,41	0,30	0,82	0,20	0,07	0,15

TABLE A.1. Distribution of the ratios: Electricity on total energy expenditure, and Energy expenditure on total GVA, for NACE 2-digit sectors, in 2018

Notes: p50 stands for the median and IQR stands for interquartile range.