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Energy Intensity and Energy Demand: A Case Study for the Italian Industrial Sector

Buzzigoli, L.[*] and Viviani, A.

Dipartimento di Statistica "G. Parenti", University of Firenze, Italy

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ABSTRACT: The paper presents an analysis of both energy intensity and energy demand for the Italian industrial sector. The aim of the paper is twofold: making a decomposition of energy intensity at the aggregate level and modeling energy demand at the firm level. The decomposition of energy intensity shows different patterns for the different sub-sectors in the period of interest. In the micro approach, panel data are used to investigate whether firms' energy demand varies according to their dimension, to production factors' price dynamic and to the sub-sector energy intensity. This kind of application at firm level represents a novelty in the empirical literature on energy in Italy.

Key words: Energy, Intensity, Decomposition, Panel data, Demand, Models

INTRODUCTION

The interest on energy economics was renewed in the last two decades by the increasing interdependence and uncertainty of the energy market (European Commission, 2010) and by the emerging issues on sustainable development (Robertson, 1999). A recent review of the most influential papers can be found in Tol & Weyant (2006): research topics range from environmental issues to corporate planning, from energy commodities price volatility to energy market regulation. One of the most popular field of study is the analysis of energy intensity and its decomposition at various levels of disaggregation, to split efficiency and structural determinants (Ang & Na Liu, 2007). The vast literature on the subject reports methodological contributions (Ang & Zhang, 2000, for a review) and also many empirical applications (e.g. Na Liu & Ang, 2007). In Italy, energy intensity indicators are developed and monitored by the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA): some contributions regarding industry describe sector and sub-sector trends and evaluate efficiency in energy consumption (Cardinale & Verdelli, 2008), but the only recent analysis in energy intensity decomposition is that in Buzzigoli & Viviani (2009), who investigated aggregate and sub-sector data in the period 1971-2004. The results displayed both the need for an update of the application and a further analysis on firm-level data, related to the availability of a panel data-set of firms developed by ISTAT. This panel contains individual information on a number of economic and financial variables, including energy cost, and gives us the opportunity to analyze energy demand at firm level (Destais *et al.*, 2007) and to relate it to the sub-sector energy intensity values obtained in the macro analysis.

The paper is organized as follows. The following section presents the data and introduces the methods used in the index decomposition and in the longitudinal demand analysis. The next section discusses the results obtained in the applications. Some final considerations close the paper.

MATERIALS & METHODS

Energy intensity is a widely used indicator to analyze trends in energy consumption, defined as the amount of energy used per unit of output, and is generally assumed as the most feasible indicator for energy efficiency in economic analysis. Our first application deals with energy intensity decomposition. Models for energy demand are usually applied at the aggregate level and generally focus on the demand and the substitution of various energy sources and on the role of energy as a productivity factor (and its complementarities with other factors). Our second

*Corresponding author E-mail:buzzigoli@ds.unifi.it

application refers to an energy demand model estimation at the firm-level. The energy intensity decomposition refers to the economic version of the indicator (I_t), where energy is measured in physical units (E_t), and output is measured in value (Y_t):

$$I_t = \frac{E_t}{Y_t}$$

At the national level, energy intensity is defined as the energy consumption per unit of GDP (taken at constant prices), while at the industrial level the production is measured by means of value added. Very often the unit of measurement for energy consumption is the "tonne of oil equivalent" (toe) and its multiples, which permits to compare and aggregate different fuels, originally measured in different units. Note that they should be regarded as measures of energy content rather than physical quantities. Nevertheless, aggregate energy intensity is a rough indicator, i.e. the result of a combination of different factors that can have very different patterns: a higher technical efficiency; a change in the structure of the economic system; a growth of the value added. Therefore, it can be useful to evaluate trends in the overall energy use. However, its interpretation is difficult, as it depends not only on the overall efficiency of the economy, but also from the production and transport system, the climate, and so on. In Italy the sources of aggregate energy data are the Ministry for the Economic Development (MED, 2000-2009) and ENEA (2000-2009), while the source for value added is ISTAT. The data are annual and refer to the period 1990-2008. The time–span is limited, because ENEA recently modified the classification of economic activities used in the National Energy Balance (BEN). Moreover, in 2005 ISTAT adopted the chain index method for estimating real aggregates dynamics in National Accounts and introduced ATECO 2002 (Italian version of NACE rev.1.1). Another key problem was the different classification of the economic activities used in the energy reports and in the ISTAT publications: for that reason the ATECO two-digit sub-sectors were aggregated to the BEN sub-sectors to match energy data. Italy has always shown a low value of energy intensity, when compared with the other European countries, primarily because the energy efficient technologies were developed in order to decrease energy imports. Another important stimulus to reach energy efficiency is provided by Italy's high energy prices. Nonetheless, while some countries showed a progressive and considerable decline in energy intensity in the last 20 years, Italy remained rather stable, although a slight recent decrease. At present energy intensity in Italy is very similar to the one of the EU-15 (Fig. 1).

In Italy, the share of industry final energy consumption shows a decline (from 33.6% in 1990 to 28.7% in 2008); nonetheless, industrial consumption is still more than one-quarter of all energy consumed. The energy consumption in the industrial sector progressively decreased since 2004 and – at the same time – the value added increased (with the exception of the 2008 fig.). Therefore, energy intensity at the industrial level has recently shown a progressive decline.

The general index hides very differentiated values and patterns at sub-sector level; however, this is particularly evident looking at Table 1, which presents the values of energy intensity for the industry and for the BEN sub-sectors for five years. Fig. 2 presents the corresponding index numbers (1990=100) for the whole period.

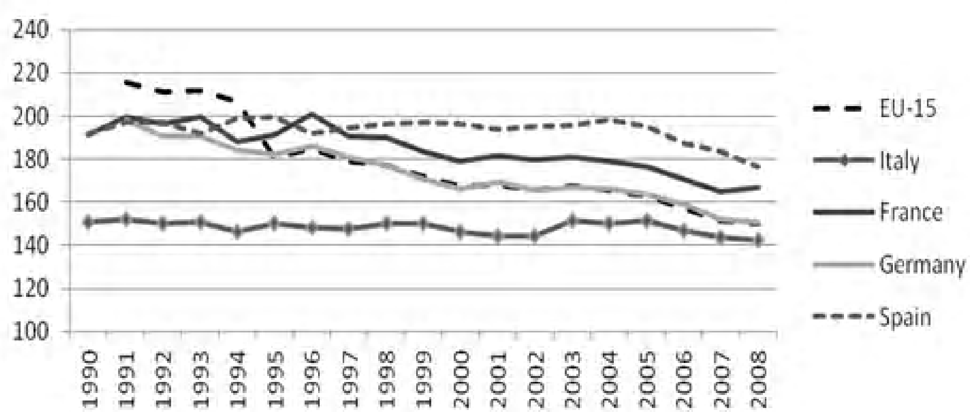

Fig. 1. Energy intensity of the economy. Gross inland consumption of energy divided by GDP (kilogram of oil equivalent per 1000 Euro) (Source: Eurostat Database)

Table 1. Energy intensity in industry and in BEN sub-sectors

	1990	1995	2000	2005	2008
Industry	147.9	143.6	146.5	149.2	134.8
Mining	85.0	93.2	86.6	82.3	85.2
Basic metals	1455.6	1015.1	1065.4	1233.3	1166.9
Machinery	42.4	50.5	57.1	58.6	53.3
Food	114.3	137.6	158.3	176.2	153.5
Textile	77.1	87.1	100.2	102.9	75.2
Non metallic minerals	655.7	629.8	759.1	746.0	731.9
Chemicals	517.1	484.5	384.6	385.3	343.1
Paper	151.3	184.7	193.6	217.8	202.5
Other manufacturing	151.2	59.6	65.1	75.1	69.2
Construction	1.8	3.5	2.9	3.4	3.3

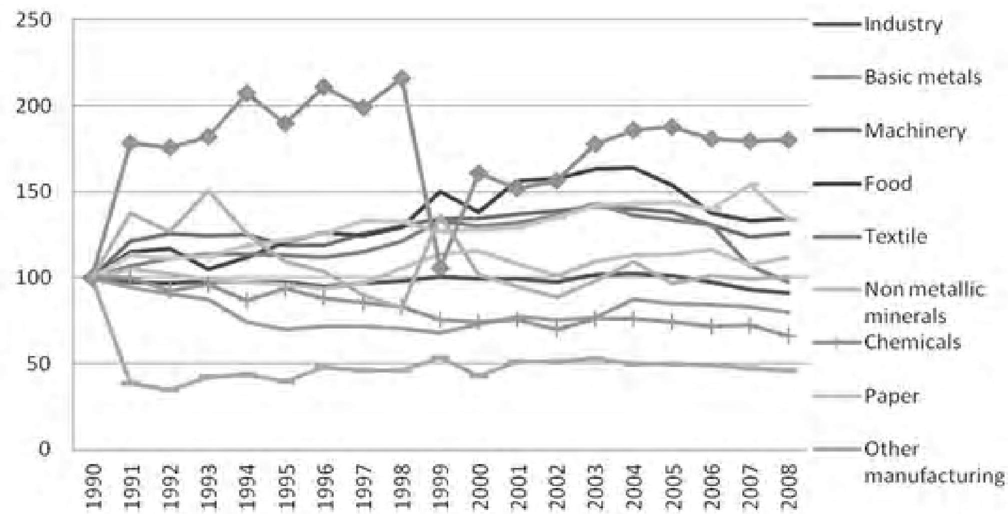

Fig. 2. Energy intensity in industry and in BEN sub-sectors: index numbers (1990=100)

The energy intensity patterns have been influenced by two concurrent drivers: the internationalization/globalization process and the reorganization of the sub-sectors composition after the industrial restructuring in the 1980s (Bugamelli *et al.*, 2009). The decomposition of energy intensity could be of help in evaluating the impact of both structural variations and effective changes in sub-sector energy intensity on changes in industry's total intensity.
For each branch *i* at time *t* we can define energy intensity as:

$$I_{it} = \frac{E_{it}}{Y_{it}}$$

and the production share as:

$$S_{it} = \frac{Y_{it}}{Y_t}$$

where E_{it} is the energy consumption of branch *i* and Y_{it} is its value added.

These quantities can be used to express aggregate energy intensity as a composition of intensity (I_{it}) and structural (S_{it}) features:

$$I_t = \frac{E_t}{Y_t} = \sum_i \frac{E_{it}}{Y_t} = \sum_i \frac{E_{it}}{Y_{it}} \frac{Y_{it}}{Y_t} = \sum_i I_{it} S_{it}$$

Therefore, the total energy intensity is partly due to the energy intensity of the various sectors and partly to the economic relevance of the sectors themselves (also called structural effect, that is measured by production share).

From a temporal perspective, decomposition methods can be used to evaluate whether a change in aggregate energy intensity can be imputed to a real shift in energy intensity of the various industrial sectors or to a structural change in activity composition. More specifically, the aim of decomposition is to disentangle the effect of the intensity and structural changes on the variation of aggregate industrial intensity. Adopting a multiplicative form we obtain:

$$ {}_0D_T^{tot} = \frac{I_T}{I_0} = {}_0D_T^{int} \cdot {}_0D_T^{str} $$

with D^{int} and D^{str} denoting, respectively, the intensity and the structural effects.

Several methods were proposed to make the decomposition: (for a general classification see Liu & Ang, 2003). We choose the Fisher ideal index, which has a number of desirable theoretical properties. In particular, it produces a perfect decomposition and doesn't require that the measure of sub-sectors activity is additive (and in our case it isn't, because chained values are not additive). After the estimation of Laspeyres and Paasche indexes for intensity and structure components, the Fisher counterparts can be easily built as in Table 2.

The decomposition produces (as in the price index case, Diewert, 2001):

$$ \frac{I_t}{I_0} = {}_0F_T^{int} \cdot {}_0F_T^{str} $$

Our second application, aimed at estimating an energy demand model at firm level, refers to a dataset derived from a panel of 13573 firms developed by ISTAT (Biffignandi and Zeli, 2010), covering the years 1998-2004. It contains information from different sources: the census of Italian firms; the so-called SCI survey ("Sistema dei Conti delle Imprese", that surveys all firms bigger than 20 employees); the so-called PMI survey ("Piccole e Medie Imprese", that covers the firms with employment in the range 20-100); the annual reports of incorporated firms collected by the Central Balance-Sheet Data Office of Italy. We selected only the industrial firms (with 20 employees or more) that remained in the same two-digit ATECO (Italian edition of NACE Rev.1.1) sub-sector during the seven years and that declared a cost for energy inputs in each year: the final panel contains 1683 firms and can be denoted as a short, balanced panel. The percentage distribution of value added per BEN sub-sector for the 1683 panel firms resembles the corresponding distribution calculated on the ENEA/ISTAT macro-data for the same time-span, with a few exceptions. The measures based on the national currency were deflated by Istat (with base year 2000). In order to integrate the dataset with the information on energy intensity presented previously, firms were classified also by BEN sub-sector. The firms' energy demand model is based on a classic KLE production function specification (Pyndick, 1979), in which the value added (Y) is the output and capital (K), labor (L) and energy (E) are the inputs:

$$ Y = f(K, \mathrm{L}, \mathrm{E}) $$

The corresponding energy demand function, specified under the usual hypothesis of a competitive markets, can be written as:

$$ E = g(\mathrm{Y}, p_K, p_L, p_E) $$

where, p_K, p_L and p_E are the input prices.

The peculiarity of our analysis, given the characteristics of the dataset and the limited time-span of the panel, suggests an empirical specification of the function based on a further hypothesis. We assume that the relevant technological features in this field of application are related to energy efficiency issues. Thus they can be properly quantified by means of the energy intensity measures available at the sector level (*Ie*), which varies over time and over sectors. In other words, we consider that different activity sectors employ different technologies that need different levels of energy intensity. We use the variable *Ie*, which is the energy intensity (employed in the previous decomposition analysis) of the firm BEN sub-sector, to capture these "structural" differences in the model: the value of the variable is constant for each firm of the same BEN sub-sector, but, obviously, varies over the time span. Therefore, the demand function - to be estimated at the firm level - can be formulated as:

$$ E = g(\mathrm{Y}, p_K, p_L, p_E, I_e) $$

Table 2. Index decomposition scheme

	Laspeyres	Paasche	Fisher
Intensity	${}_0\mathrm{L}_T^{int} = \frac{\sum_i I_{it} S_{i0}}{\sum_i I_{i0} S_{i0}}$	${}_0\mathrm{P}_T^{int} = \frac{\sum_i I_{it} S_{it}}{\sum_i I_{i0} S_{it}}$	${}_0\mathrm{F}_T^{int} = \sqrt{{}_0\mathrm{L}_T^{int} \cdot {}_0\mathrm{P}_T^{int}}$
Structure	${}_0\mathrm{L}_T^{str} = \frac{\sum_i I_{i0} S_{it}}{\sum_i I_{i0} S_{i0}}$	${}_0\mathrm{P}_T^{str} = \frac{\sum_i I_{it} S_{it}}{\sum_i I_{it} S_{i0}}$	${}_0\mathrm{F}_T^{str} = \sqrt{{}_0\mathrm{L}_T^{str} \cdot {}_0\mathrm{P}_T^{str}}$

The log specification, labeled as Model A, is the following:

$$\ln E_{it} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln p_{Kt} + \beta_3 \ln p_{Lt} + \beta_4 \ln p_{Et} + \beta_5 \ln Ie_{jt} + u_{it}$$

where i denotes the firm (i=1,2,…1683), t the year (t=1,2,…7), j the BEN sub-sector of each firm (j=1,…, 9); E_{it} is the (deflated) expenditure for energy of firm i at time t; Y_{it} is the (deflated) output value for the firm i at time t; p_{Lt} the labor cost index at time t; p_{Kt} the index of capital user cost price at time t; p_{Et} the index of real energy prices at time t; Ie_{jt} the energy intensity of the firm's BEN sub-sector j for the time t.

The variables *E* and *Y* are taken from the Istat panel dataset. The labor cost index p_L is produced by Banca d'Italia (Banca d'Italia, 2003, 2004, 2005); the capital user cost price used to calculate p_K is produced by Istat; p_E is available from the International Energy Agency. We refer to a composite energy price index because the prices of the different energy sources are not available; moreover, the composition of energy consumption by energy source didn't vary significantly in the considered time-span. All the indexes are on basis 2000=100. *Ie* is the variable, produced by ENEA, used in the previous decomposition analysis. On the basis of the well-known theoretical result regarding the factor demand function, we can substitute the factor prices with the price relatives (in terms of capital), obtaining the following parameterization, labeled as Model B:

$$\ln E_{it} = \gamma_0 + \gamma_1 \ln Y_{it} + \gamma_2 \ln(p_{Et}/p_{Kt}) + \gamma_3 \ln(p_{Lt}/p_{Kt}) + \gamma_4 \ln Ie_{jt} + u_{it}$$

We estimated random effects panel models for three main reasons: N is large and T is small; the random effects approach allows to generalize the inference beyond the sample used in the model; the hypothesis that omitted individual variables are not correlated with the predictor variables seems appropriate. Moreover, the variable *Ie* captures fixed effects and this has been explored comparing the fixed effects model without *Ie* and the proposed random effect model (with *Ie*).

RESULTS & DISCUSSION

The results of our analysis on the energy intensity decomposition and on the energy demand can be summarized here. In Fig. 3 we present the result of the decomposition when the intensity change is evaluated on a fixed basis (1990=1), while Fig. 4 refers to the yearly growths. The relevant annual increase in total energy intensity in 2003 is due to the increase in energy consumption (+3.2%) and the parallel decrease in the value added (1.5%) and produces an intensity value which is higher than the one in 1990. Both graphs illustrate that in the period 1990-2003 the structural and intensity drivers often have opposite effects; annual changes never exceed the interval ± 5% and in the last four years they show a persistent decline. Moreover, in 2004-2008 the global change in the energy intensity resembles the one of F^{int}: therefore, in the last five years had the composition of industrial sector not changed since 1990, energy intensity dynamic would have been very similar to the actual one. The global change seems to be mainly due to the decline in energy intensity in the various sub-sectors. On the contrary, had energy efficiency been fixed as its 1990 levels for all industrial sub-sectors, changes in economic activity would have led to a lower increase in energy efficiency. The results of the demand model estimation are in Table 3 (Model A) and in Table 4 (Model B).

The results are similar. First of all, both models confirm the expected result of a direct relationship between the demand for energy (measured by deflated expenditure for energy) and firm dimension. As far as Model A is concerned, the capital price index coefficient is not significant: this result could be due to the absence of substitution effect between capital and energy demand in the short term. On the contrary, the coefficients of energy and labor price indexes are significant, but the sign of the energy price coefficient seems ambiguous because it is different from the expected one. A possible explanation refers to the aggregate nature of the price index: first of all, the price of energy differs on the basis of the energy consumption level but the composite index is not able to highlight this phenomenon; secondly, the price index sums up the prices of the different energy sources used by the firms and the single prices have had different dynamics. Furthermore, energy price market regulation could affect the result. When the price relatives are considered in Model B, these results are confirmed. Finally, the significance of the BEN-intensity coefficient in both cases suggests that energy demand is linked to the different sub-sector energy intensities. Therefore, the technological asset of the sub-sectors can be considered as an important driver of energy demand at firm level.

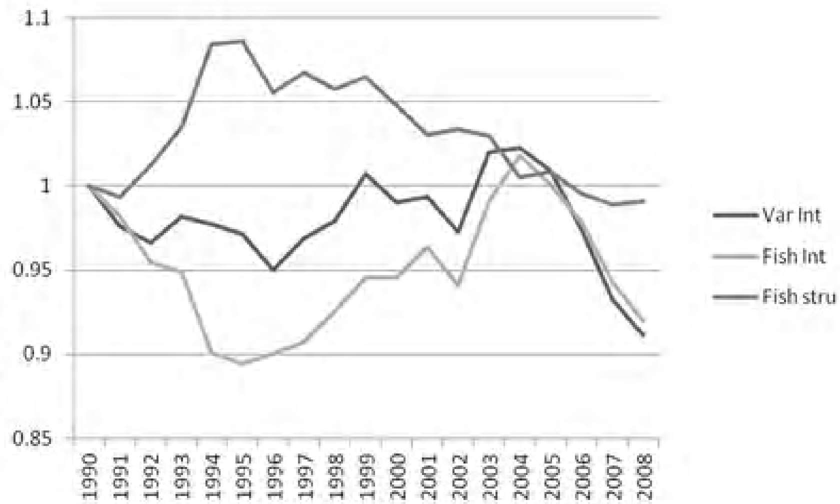

Fig. 3. Decomposition results for industry energy intensity (1990=1)

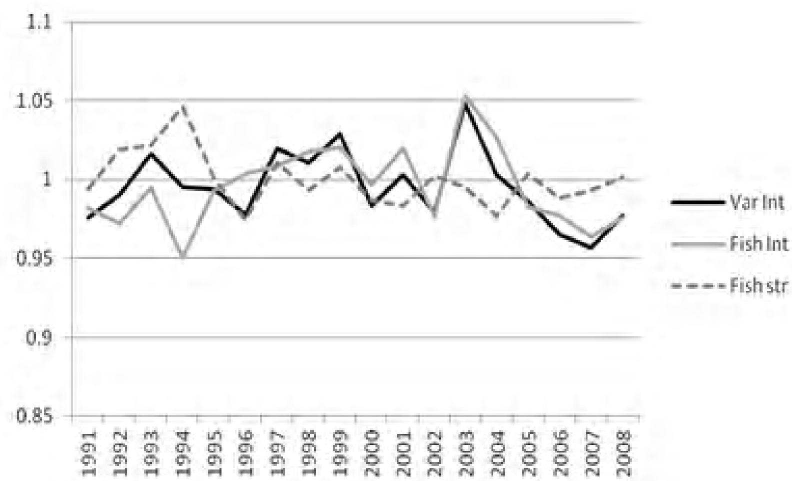

Fig. 4. Decomposition results for industry energy intensity (annual change)

Table 3. Energy demand - Model A and Model B estimation results (std errors in parentheses)

Model A		
Variable	**Coefficient**	**s.e**
constant	-6.06**	1.09
$ln\, Y_{it}$	0.85**	0.17
$ln\, p_{Kt}$	0.17	0.25
$ln\, p_{Lt}$	-0.79**	0.23
$ln\, p_{Et}$	1.06**	0.32
$ln\, Ie_{jt}$	0.32**	0.02

Model B		
Variable	**Coefficient**	**s.e**
constant	-4.85**	0.79
$\ln Y_{it}$	0.85**	0.02
$\ln(p_{Et}/p_{Kt})$	1.11**	0.32
$\ln(p_{Lt}/p_{Kt})$	-0.95**	0.22
$\ln Ie_{jt}$	0.32**	0.02

** denotes the rejection of null hypothesis at 5% level

CONCLUSION

To analyze the role of energy in the Italian industrial sector, the paper starts with a decomposition analysis at aggregate level which aims at understanding the characteristics that underline changes in industrial energy intensity in Italy for the period 1990-2008.

We observed two different temporal patterns: from 1990 to 2003 the intensity and the structure effects have opposite dynamics and the actual intensity change is intermediate (although it shows almost always a decrease, like the 'pure' intensity effect F^{int}); from 2004 onwards, the pattern of actual intensity change resembles the one of F^{int}. Overall, structural changes play a minor role. On the basis of this result, an econometric micro-analysis is proposed on a panel data-set of firms developed by ISTAT: the 'energy intensity variable' was included in two different specifications of the same energy demand function. So, the model specifying the drivers of the energy demand at the firm level, according to a classic approach, is integrated by a technological assumption regarding energy efficiency issues (all the firms belonging to the same BEN sub-sector share the same energy intensity). First of all, the results show the significance of the firm dimension as an explanatory variable of energy demand. Moreover, the relevant role of BEN energy intensity is confirmed, as expected on the basis of the decomposition analysis. As far as the production factors prices are concerned, the results are more ambiguous, because the energy price coefficient is significant but with a different sign from the expected one: changes in energy price could imply an asymmetric change in the derived demand for energy. A possible explanation refers to the aggregate nature of the price index and to the energy market specificity. In conclusion, some remarks on the data used for models estimation are necessary due to the fact that the firm-level panel data have some shortcomings. First of all, the balance sheet data do not distinguish the cost of energy for heat and power from the cost of energy for the production process. Secondly, the data contain only an aggregate information on energy consumption and it is impossible to distinguish the expenditure for the different energy sources. Moreover, information on physical energy consumption are not available: therefore, we couldn't estimate the firm-level energy intensities in order to include in the model also a proxy of the production process energy efficiency. Finally, the panel is a subset of the firms included in the original ISTAT panel and it can be plausibly used only for an exploratory analysis. All in all, our paper represents a first contribution to understand the forces that drive energy intensity changes in the Italian industry: it conjugates macro- (using price variables), meso- (using energy intensity by BEN sector) and micro-evidence (firm-level variables) to go beyond simple descriptive analyses, estimating a model based on the classical production theory. This opens interesting hints for future further studies when updated panel data will be available.

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