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Do manufacturing firms react to energy prices? Evidence from Italy[1]

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Abstract

The reaction of energy demand to price changes is a key policy issue as it describes the economy's reaction to changes in market conditions or to policy interventions. The issue is even more important for the Italian economy, highly exposed to energy price changes, given its almost complete fossil fuel-related energy dependence, environmental sensitivity and highly fragmented industrial structure. Besides the policy issue, there is also an important methodological debate, concerning the best way to evaluate energy demand elasticities, looking at alternative models, data and elasticity definitions. After a discussion of the main methodological issues, this paper presents an estimation of demand elasticities (by factors and by fuels) for Italian industrial firms, by using a microeconomic panel in a two-stage translog model. By using cross-price and Morishima elasticities, we derive information on the magnitude and asymmetry of firms' reaction to price changes. Moreover, the use of the micro-dataset enables the highly heterogeneous Italian industrial sector to be considered: results are discussed according to sector and firm dimension. These estimations constitute an important cornerstone of energy demand by Italian industrial firms, given that empirical literature is particularly rare on the Italian case study.

Keywords: Capital-energy substitution, fuel substitution, microdata, panel estimation
JEL: C33;D2; Q4

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1. The need for policy evaluation tools

As Europe has limited energy reserves, it has to import the majority of its energy, and the price being decided by world markets, forecasting and reducing impacts of possible price increases in the near future is a central issue. The European energy strategy is therefore focused on lowering energy dependency (by expanding renewable energy sources and increasing energy efficiency) and limiting the pass-through of world price increases on consumer welfare and firms' competitiveness through a more efficient European market. On the other hand, European climate strategy aims at setting a unique price for carbon so as to implement the 'polluter pays principle' and give a sign of the real cost of releasing greenhouse gases by burning fossil fuels. The price signal is designed to induce consumers and firms to change their energy mix towards new products and inputs with a lower environmental impact. Pursuing both these ambitious – and apparently contradictory - goals involves the use of an enormous amount of resources and, at the same time, a significant change in consumers and firms' habits and behaviour, which environmental and energy policies should stimulate with all the available instruments.

Looking at firms, the reaction of agents to the price signal, whatever the reason of the price change (a result of scarcity, the market power of producer countries or deliberate, environmental-related tax change), is generally speaking good news as regards both policy perspectives: a "reactive" curve – where reactivity is measured by curve elasticity – usually signals the ability to avoid the price increase, by either greater energy efficiency, a change of the energy mix or general tax-shifting behaviour. Some of these positive reactions may be associated with a win-win perspective: if energy efficiency improves after a price increase, it can be said that there were unexploited opportunities for saving resources that only became evident after the price shock or the price signal forced the firm to invest in innovative and energy-saving technologies.

However, an energy price increase has a lot of potentially negative and politically-sensitive impacts: adverse effects for the smaller and innovative firms, general loss of competitiveness and delocalization (or carbon leakage) are just some of the potential threats. Answering the question of who would be affected by a price increase, or how much the energy mix can change as a consequence of a hypothetical pigouvian tax policy therefore appears to be a key starting point for any national or European strategy plan. Besides the policy issue, there is also an important methodological debate, concerning the best way of evaluating energy-demand elasticities. As usual in social sciences, it is impossible to address this question in one direction only, as different techniques shed light on different aspects: the availability therefore of different models and data is an essential factor for designing a sound policy approach in this strategic field. After a brief overview of the most important methodological caveats and the main findings of the empirical literature (paragraph 1.1), section 2 resumes the translog model and the specific elasticity definitions adopted in this paper. Section 3 describes the dataset, whereas in section 4 estimation results are discussed. The final section concludes.

1.1 Some methodological issues

All impact estimations – for which elasticities play a key role - are strongly model-dependent, not only with regard to the ability to implement policy details and to identify various aspects of policy effects and feed-backs, but also on the underlying crucial theoretical hypotheses and the estimation strategy adopted. Over the last two decades there has been a plethora of studies on the impact of changes in energy prices on the economy, based on the use of economic models following different approaches. A taxonomy of modelling tools can be designed according to some characteristics of the models (micro vs. macro models or, among the latter, input-output (IO), input-output+econometrics, and computable general equilibrium (CGE) models)[2]. While the basic IO energy model is static, with fixed technological coefficients and without price effects, both macro-econometric and CGE models can be dynamic and therefore theoretically suitable to understand agents' reactions to policy or price variations. CGE models, in particular, can provide important and detailed information on the economy-wide interactions and distributional effects, but do not rely on endogenous estimations of equation parameters, since behavioural and technological parameters are "chosen" by the modeller through a procedure called calibration. This method consists of assigning values to equation parameters (elasticities of substitution, income and supply elasticities, etc.) on the basis of information drawn from various empirical studies in the literature and specific

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[2] See Bardazzi and Pazienza (2014).

databases[3]. Conversely, microeconometric models can estimate critical parameters – such as the elasticities of production factors and inter-fuel substitution – on very large survey data allowing for differentiation between firms grouped according to different characteristics but their main drawback is that they do not consider the overall efficiency effects of a price signal because they lack an economy-wide perspective. It is important to stress that the advantage of microdata does not only consist of considering firms' heterogeneity with regard to dimension or industries: microdata can also give some clues on different production functions and technological choices within a specific sector of activity. This can be important because with macro data, production function characteristics and energy mixes can only be analyzed by looking at a weighted average of usually highly heterogeneous agent choices. We would recall that this is the main argument of Solow (1987) claiming that the estimate of factor substitution with aggregate data on inputs and output may be misleading because changes in the product mix are likely to occur when factor prices change, therefore elasticity of substitution estimates based on aggregate time-series are likely to be biased downward.[4]

Given the need for a reliable empirical basis for a good policy design, it is clear from the above consideration that macro and micro elasticity estimation should jointly be considered in order to establish a good starting point for the analysis.

However, different models and data characteristics are not the only methodological problems. Even elasticity definition is widely disputed in the literature, especially where the substitution or complementarity between factors and/or energy inputs – for a given level of output - constitutes the focus of the analysis. Indeed, we can consider an absolute or a relative approach: in the first , elasticity measures the change in quantity of one factor after a variation of the price of another factor, as in cross price elasticities and Allen-Uzawa elasticities. In the second approach the focus of the analysis is on how the relative usage of two factors (the level of one relative to the other) is influenced by one input price (as in Morishima elasticities) or by the relative input prices (shadow elasticities of substitution). These elasticities differ for the underlying hypotheses and explicative capacity: to give just one example, Allen-Uzawa elasticity, although widely used in the empirical literature, may be considered

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[3] In other words, econometric studies based on different countries, time periods and data are ‘imported’ in the CGE model to define suitable parameters so that the resulting equations are numerically consistent with the available data at the base year. An example of a CGE database is the GTAP (Global Trade Analysis Project) which includes a specific behavioural parameters file which is fed directly into the GTAP Data Base along with an Energy Data Base. In general these models are not validated against historical data, but in some cases parameters are revised (with new estimates from the literature) to reproduce the variability of the distribution of observed key variables through a stochastic simulation approach. See, as an example, Beckman et al. (2011).

[4] On this issue see also Miller (1986).

uninformative when more than two factors are used[5]. Moreover its definition implies symmetry in the reaction of two factors (or energy inputs): according to Allen-Uzawa elasticity, the change of factor i after the change of the price of factor j is identical to the change in factor j due to a change in the price of factor i, a hypothesis clearly too limiting on empirical grounds. As we chose to include in the empirical analysis four factors and four energy inputs (for which the symmetry restriction would have been difficult to justify), in this paper cross price and Morishima elasticities are calculated as described and discussed in the following paragraphs (par. 2.2 and 4.2).

As the specific elasticity measure used can influence the final results (i.e. if two factors can be described as substitutes according to one definition and complements according to another), it's very important to take definition into account before comparing one empirical estimation with another. Moreover, hypothesising a given output level[6], as usual in this kind of literature, in the presence of only two factors of production substitutability between the two is an unavoidable result. Looking at a multifactor production function, on the contrary, the reaction of one input in response to a change in the price of another input is influenced by the behaviour of all the other inputs, and for this reason it is particularly important to consider as many inputs as possible, avoiding the omitted variables bias. This is essential for the never-ending energy-capital substitutability debate: if energy and capital are complements, an increase in the price of energy might also cause a decrease in the optimal level of capital and, as a consequence, may obstruct productivity and innovation. In the aforementioned hypotheses, however, caution must be used when interpreting the results: an increase in energy prices may trigger a substitution process leading to more capital, but the simultaneous movements in all other inputs may lead to a final net result of complementarity between energy and capital[7].

Finally, in order to fully interpret a significant reaction of energy cost after a price variation it is important to separate the ordinary improvements in energy efficiency from innovative investment paths. A hypothesis on technical change may therefore be crucial in interpreting the substitutability - complementarity debate: neutral or

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[5] For a survey of the main issues relating elasticities and an empirical application of several measures (Allen-Uzawa elasticities, cross-price elasticities, Morishima and shadow elasticities) to Italian manufacturing firms see Bardazzi et al. (2012) and references cited in that study.

[6] The hypothesis that, after the price increase, the total level and the composition of output is constant is crucial in this kind of analysis. It may be noted that the assumption of a "homogenous output" is much more plausible with micro data than in a macro model.

[7] For this kind of decomposition see Berndt and Wood (1979) and Broadstock et al. (2007). These potential opposite effects can be even more difficult to interpret using macro data, as the ordinary substitution effects within one firm may be compensated by opposite choices by other firms in the same sector of activity.

non-neutral technical progress with regard to inputs or fuels may alter the interpretation of estimated elasticities[8].

1.2 Empirical studies: results and caveats

As a very general finding, the empirical literature has identified non-negligible factors and fuel elasticities, especially in the longer run: a price change generally induces a substitution process towards the more cost-effective solution. As previously discussed, this can be considered good news, because there is room for a positive reaction to market or policy-induced signals, by increasing a formerly unsatisfactory energy efficiency or by investing in innovative machineries.

However, considering the energy capital substitutability debate, neither the sign nor the magnitude can be easily averaged. Berndt and Wood's (1975) paper was among the first studies to find complementarity between energy and capital in the US economy and after this pioneering contribution, a very large number of empirical studies followed[9]. For the reason discussed in the previous paragraph, meta-analyses are particularly difficult on this issue: models, estimation strategies, data characteristics and elasticity definitions are particularly heterogeneous[10]. In particular there is a supposed dichotomy between time series and cross-section studies, where time series studies tend to estimate short run effects, finding complementarity whereas long run effects and substitutability can be found in cross-section studies. All in all, substitution processes take time, thus long run elasticities are always larger than short run ones and therefore complementarity in the short run can become substitutability in a longer run (Koetse et al., 2008).

According to Broadstock et al. (2007), notwithstanding this methodological variability, energy and capital typically appear to be either complements or weak substitutes. More in detail, empirical results tend to find substitutability more easily in US data, compared to EU and other areas; however, as previously discussed, estimation greatly differs according to data and model choices. Cross country panel estimations on Oecd countries also generally find complementarity between energy and capital (Fiorito and van den Bergh (2011) and Paglialunga (2012) are recent examples). However, Kim

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[8] For empirical estimation regarding the role of technical change and interfactor and interfuel substitution see Broadstock (2008) and Kratena (2003).

[9] For a survey of studies on international energy elasticities up to the early Nineties see Atkinson and Manning (1995).

[10] See Raj and Veall (1998) for a sensitivity analysis on the role of theoretical restriction on factor substitutability estimation results.

and Heo (2013) stress that the assumption of considering energy as a homogeneous component can lead to a non-negligible bias: they find complementarity between capital and fuels and substitutability when capital and electricity are taken into account.

In general terms, interfuel substitution has been a long-running issue in empirical analysis and its role is even more important since the widespread use of carbon policies (carbon taxes or Emission Trading Schemes) designed to induce substitution processes in energy choices towards the least emission mix. A recent meta-analysis by Stern (2012) provides a general overview of empirical studies on interfuel potential, stressing as usual the key role of different methodologies and data characteristics. As a general finding, Stern finds non-negligible substitution possibilities (especially if coal is involved), but the magnitude of elasticities tends to decrease with increasing levels of data aggregation: substitution possibilities at a sectoral level emerge while at the total activity level a fixed energy input technology can be considered the most plausible result, as a general confirmation of Solow’s argument. The importance of a wide range of information, embedded in firm level data, has recently been emphasized by a new strand of studies looking at the effects of ETS on firms' behaviour. Linden et al. (2013), as an example, find different interfuel substitution possibilities depending on firm and plant size as opposed to location, which seems to have a minor role in fuel mix flexibility.

Indeed empirical estimations on Italy's interfactor and interfuel substitutability are very rare in the literature. Italy has been included in several OECD cross country estimations[11] but, as far as we know, there is no firm level study which attempts to assess production function flexibility in relation to changes in energy prices. In this paper we aim to fill this important gap by looking at interfactor and interfuel substitution possibilities in Italy through the micro level data of manufacturing firms.

2. Theoretical model and elasticities

2.1 The model

In this study the translog model developed by Christensen et al. (1973) is applied, a flexible functional form that does not impose any a priori restriction on the

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[11] In addition to interfactor estimations discussed above, for interfuel estimations that include Italy see Morana (2000), Serletis et al. (2009), Renou Maissant (1998) among others. Results from Morana (2000) and Serletis et al. (2009) are discussed below.

elasticity of substitution which is the main object of this analysis. This function is used here to model both the producer's decision as regards the choice of individual fuel inputs, and as regards the demand for production factors such as capital, labour, materials and total energy. This approach has been used in several empirical studies on interfactor and interfuel substitution.[12]

The translog model assumes a general indirect cost function (given the equivalence of production and cost functions) and applies Shephard's lemma to determine the demand functions of the production factors and the share equations. The n-equation system of input factor shares to be estimated can be written as:

$$S_i = c_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j \qquad j = 1, \dots i, \dots n \qquad (1)$$

where *j* are the n factor inputs, S_i is share of factor *i* on total cost, and *p* are input prices.

The cost function must be homogeneous of degree one in prices, therefore the usual restrictions on parameters are imposed: adding up, homogeneity and symmetry of substitution (Christensen et al., 1973).

As singularity may occur in the system of cost shares as in (1), one equation must be dropped from the system. By dividing all the prices in the remaining set of equations by the price of the *k-th* dropped input, it is possible to omit that equation and a system of (n-1) simultaneous cost share equations is estimated instead:

$$S_i = c_i + \sum_{j=1}^{n-1} \gamma_{ij} \ln p_j / p_k \qquad j = 1, \dots i, \dots n-1 \qquad (1\,b)$$

The dropped input is used as the *numeraire* input and the parameters of its equation are calculated using the summing, price homogeneity and symmetry conditions as constraints.

The system of factor share equations can be used to investigate the demand for aggregate energy and the substitutability/complementarity relation between energy and other aggregate inputs. However, the same specification can be extended to

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[12] For reviews see Atkinson and Manning (1995) and Stern (2012).

model the demand of individual energy inputs. In doing so, we should assume that the cost function is weakly separable, as follows

$$C = C[P_E\left(P_{E_1}, \ldots P_{E_n}\right), P_L, P_M, P_K, t]$$

where P$_E$ (·) represents a homothetic sub-cost function where sub-energy inputs are separable from capital, labour and materials. The energy sub-cost function can be represented by a translog function and again, applying Shephard's lemma, we can obtain a system of demand functions for individual energy types, E$_1$, ..., E$_n$, in terms of shares in the cost of the energy aggregate similar to those in equation (1):

$$S_{E_i} = c_i + \sum_{j=1}^{m} \gamma_{ij} \ln p_j \qquad j = 1, \ldots i, \ldots m \qquad (2)$$

This is the stage of the cost-minimizing decision allowing the producer to determine the demand for different fuels. The usual restrictions on coefficients are imposed as described above and the system is estimated in the form of equation (1 b) that is by dropping one equation to avoid the singularity of the covariance matrix.

In this study a system with four production factors (labour (*l*), material (*m*), energy (*en*) and capital (*k*)) and an energy sub-system with four fuel share equations (electricity (*e*), gasoil (*g*), natural gas (*ng*) and fuel oil (*f*)) are estimated. The general equation for both models is specified as follows:

$$S_{it} = d_i + \sum_j \gamma_{ij} \ln(p_{jt}/p_{kt}) + \beta_i \ln(Y_i/P_t) + \delta_i \ln(emp_i) + \sum_t \tau_{it}\, year_{it} + \sum_{j \in Nace} \vartheta_{ij}\, DS_{ij} + u_{it} \qquad (3)$$

Factor demand system: $\begin{cases} i, j = l, m, en,\ k \\ t = panel\ obs. \end{cases}$

Fuel demand sub-system: $\begin{cases} i, j = e, g, ng, f \\ t = panel\ obs. \end{cases}$

Each equation is a function of the p_{jt} price of inputs, and of the level of output in real terms, Y_t/P_t , to measure changes in economic growth. Moreover, in order to consider the non-homotheticity of the underlying production function (i.e. non-constant returns to scale), the equation system is integrated with the following instrumental variables: (a) the logarithm of the number of workers as a proxy of the size of the firm (emp_{it}), (b) the year dummies (to capture calendar effects and linear technological progress)[13] and (c) sectoral dummies (DS_{ij}) (to capture the individual effects of each industry). Indeed, in some previous studies (Bardazzi et al., 2009; Bardazzi et al. 2012) it was estimated that firm size and economic activity determine differences in energy demand behaviour and in the sign and magnitude of reactions to price signals.

This two stage decision-making model was originally suggested by Fuss (1977) and Pindyck (1979) as a modelling approach to incorporate feedback effects between the factor and the fuel demand system. According to this approach there is a linkage between the energy sub-system – estimated as the first stage – and the factor model through an instrumental variable method: estimates from the interfuel model are used to compute an aggregate energy price which enters the factor demand system (the second stage model) as an explanatory variable. Moreover, the own price elasticity of aggregate energy use is included in the formulas of own and cross-price elasticities of fuel demand to account for the feedback effect between the interfactor and interfuel substitution due to an individual fuel price change (see Pindyck 1979 for details). Feedback effects between interfactor and interfuel substitution are particularly relevant in economies experiencing rapid economic growth with upward shift in wages and increase in energy consumption with fuel-price changes. These phenomena characterize developing countries (Cho et al., 2004) but are less significant in advanced economies. Therefore, in this study the modelling framework explained above is applied but the energy price of the factor demand system is computed from the observable data at the firm level rather than estimated so that the rich informative content of panel data and of the micro simulation model can be exploited.

2.2 Elasticities

Using the parameter estimates of model (3), several types of elasticity of substitution are calculated. Obviously price elasticities are relevant for assessing the magnitude of reaction to the policy signal especially as regards energy policy. Aware of the theoretical debate and the specific properties of different measures of substitution, in this study we focus on own and cross-price elasticities and Morishima elasticities. In the case of a translog function, an own-price elasticity of substitution can be obtained

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[13] A neutral technical progress is assumed in this specification. Although it is recognized that an assumption of non-neutral technological progress could affect the results, this standard hypothesis is supported by the short time period of the microdata used in this study (6 years) and by the classification of firms into groups according to their technological intensity (see Section 3).

by deriving each cost share with respect to the own price and, simplifying, the elasticity formula of the input in relation to its own price is derived:[14]

$$\eta_{ii} = \frac{\gamma_{ii}+S_i^2 - S_i}{S_i} \qquad (4)$$

while, for the cross-price elasticity of input *i* with respect to p_j we have:

$$\eta_{ij} = \frac{\gamma_{ij}+S_i S_j}{S_i} \qquad (5)$$

where S_i and S_j are the predicted cost shares. These cross-price elasticities measure the relative change of a single factor *i* due to a sole change of the price of factor *j*, with output and all other prices being constant.

When there are more than two inputs, Morishima elasticities of substitution (MES) provide information about the percentage change in the *ratio* of input *i* to input *j* when the price of input *j* changes by one per cent and all other prices and output are constant:

$$\frac{\partial \log(x_i/x_j)}{\partial \log p_j} =: MES_{ij} \qquad (6)$$

If $MES_{ij}>0$ inputs are Morishima substitutes: an increase in the price of *j* causes the quantity x_i relative to the quantity x_j to increase. If $MES_{ij}<0$ inputs are complements.[15] The relationship between MES and own and cross-price elasticities is as follows:

$$MES_{ij} = \eta_{ij} - \eta_{jj} \qquad (7)$$

According to (7), a change in p_j implies two effects: the impact on input *i*, given by the cross-price elasticity η_{ij}, and the effect on x_j itself. Given that for a normal good own-price elasticity is negative, we can envisage three cases for MES depending on the sign of η_{ij}: a) if $\eta_{ij}<0$ and greater in absolute value than the own-price elasticity, then MES<0 and there is complementarity; b) if $\eta_{ij}<0$ but, in absolute value, smaller than the own-price elasticity, inputs are MES-substitutes although they are classified

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[14] See Thompson (2006) for a formal derivation of the formulas.

[15] In the simple case of two inputs MES cannot be negative: it would imply that a decline in one input can be compensated by a reduction in the availability of the other input.

as complements according to cross-price elasticity; and finally c) if $\eta_{ij}>0$, MES>0 and inputs are substitutes.

MES is naturally asymmetric ($MES_{ij} \neq MES_{ji}$): two inputs *i* and *j* being MES-complements with respect to changes of the price p_j might be MES-substitutes with respect to changes of the price p_i. Even if the sign of substitution is the same, there may be a difference in elasticity magnitude and in that case it is relevant to analyse which input dominates the substitution relationship. The analysis of substitution asymmetry between production factors and also between energy types may give interesting insights into the adoption of energy-saving technologies and environmental policies.

3. Data description and estimation variables

To investigate interfactor and interfuel substitution, a micro-dataset and a micro-simulation model for Italian industrial firms built within a European project called DIECOFIS coordinated by the Italian National Institute of Statistics are used.[16] EISIS (*Enterprise Integrated and Systematized Information System*) is a multi-source business dataset based on microdata created at ISTAT.[17] In particular, to model energy taxes and fuel consumption by firm, data from the *Manufacturing Product Survey* (*Prodcom*) is matched with the main database. The resulting data cover all Italian manufacturing firms with more than 19 employees and a sample of small firms with more than 2 and less than 20 employees. These data are available for the years 2000-2005 and include information about expenditures (net of VAT) and consumption in physical units of several energy sources.[18] To our knowledge, DIECOFIS model is the only example of a firm-level micro simulation model considering the environmental and energy variables of Italian firms, which covers large corporations as well as small, unincorporated enterprises. This model and the related dataset

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[16] DIECOFIS (Development of a System of Indicators on Competitiveness and Fiscal Impact on Enterprise Performance) is a project financed by the Information Society Technologies Programme (IST-2000-31125) of the European Commission and coordinated by ISTAT. This model is designed to evaluate and simulate fiscal policies on enterprises and has been used to monitor (ex ante/ex post) the effectiveness of several policies. The model is run at ISTAT where data is produced but the Institute bears no responsibility for analysis or interpretation of the data. See Bardazzi et al. (2004) for an overview of the main features of the model.

[17] The integrated and systematized information system on enterprises is the result of an integration process of different administrative sources. The statistical register of Italian active enterprises (ASIA) has been used as a "backbone" for this integration process. Several sources have been attached: Large Enterprise Accounts (SCI); Small and Medium Enterprise Survey with less than 100 workers (PMI); Foreign Trade Archive (COE); other surveys such as the Community Innovation Survey (CIS) and the ICT Survey. All of the above ISTAT surveys are based on common EUROSTAT standards and classifications.

[18] Energy sources are electricity, coal, LPG, diesel, gasoline, metallurgic coke, petroleum coke, fuel oil, natural gas, and other minor products. Individual fuel consumption quantities are converted in Toe (Tons of oil equivalents).

capture firms' heterogeneity in applying specific policies and in estimating the behavioural reaction to a policy stimulus.

For this study an unbalanced panel of firms is created from the EISIS dataset where all firms surveyed over the 2000 to 2005 period and consuming at least one of the four energy sources are selected.[19] A total of 16,257 observations unevenly distributed across the years is available, 85 per cent of which is represented by firms with at least 100 employees because the annual survey of smaller firms is based upon a rotating sample. In previous works, the difference in demand behaviour of small and medium enterprises (SMEs) as opposed to large firms with at least 100 workers is investigated (Bardazzi et al. 2012) .

In order to estimate factor and fuel demand systems for manufacturing sectors, data on production inputs and fuels are required. For the energy demand model, prices and quantities of individual energy sources are computed from the EISIS data at the firm level on energy expenditures and consumption for each input. For the KLEM translog model, factor costs at the firm level for all inputs are available from the panel data as well. As regards prices, the price of labour is computed as the firm's total personnel expenses per hour worked from the dataset. It is more difficult, in general, to find adequate data indicators for materials and capital prices at the firm level, therefore the price index of materials and of capital depreciation from the supply and use tables (SUTs) at a two digit level of the NACE classification is used. As regards the aggregate price of energy, a weighted sum of the specific fuel prices at the firm level is computed. Indeed a large cross-sectional price dispersion for several energy sources can be observed which is due to a combination of the firm activity sector, its geographical location and the purchase quantity: large enterprises can negotiate lower prices on a special contract basis due to their large consumption while small firms are penalized with prices 10 percent above average. [20] Therefore microdata are exploited to build a price indicator where the energy consumption structure and prices at the firm level are considered.

Finally, real output is computed as the firm value of production deflated by the sectoral price index of output from the SUTs.

The Italian manufacturing sector is characterized by a very large share of SMEs and there is empirical evidence of specific behaviour by firms of different sizes concerning

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[19] Almost all firms consume at least two energy inputs. Excluding firms that do not use all four energy inputs does not significantly change the estimation results.

[20] This evidence is verified for Italian firms (see Bardazzi et al. 2009) but also for other European countries (Bjorner et al. 2001) and for US manufacturing plants (Davis et al., 2008).

their response to energy taxation and price changes (Bardazzi, Oropallo and Pazienza, 2009). In this work the focus is on a manufacturing industry breakdown according to global technological intensity, to test whether behavioural responses to changes in factor prices show peculiar characteristics depending on the embedded technology level of each economic sector. The aggregation of manufacturing industries in terms of their technological content is that used at Eurostat.[21] The level of R&D intensity (R&D expenditure/value added) serves as a criterion for the classification of economic sectors into high-technology (HIT), medium high-technology (MHT), medium low-technology (MLT) and low-technology industries (LOT).

Some characteristics of the firm panel over the 2000-2005 period are summarised in Table 1.

Energy intensity is higher for low and medium-low tech manufacturing as these categories include very energy-intensive economic activities such as the metallurgic industry, textiles, food products, publishing, and the chemical and plastic industries. All these activities play a key role in Italian manufacturing specialisation which is a source of macroeconomic imbalances along with the small size of Italian firms (European Commission, 2012). High-tech enterprises are more profitable and show cost competitiveness above average as measured by labour productivity in terms of unit labour costs.

Table 1 – Selected indicators of the firm panel (average 2000-2005)

	(%)	Energy intensity (a)	Profitability (b)	Cost Competitiveness indicator (c)
LOT Low technology	35,0	0.167	0.160	1.583
MLT Medium-low technology	29,7	0.283	0.155	1.603
MHT Medium-high technology	24,2	0.061	0.151	1.494
HIT High technology	11,2	0.092	0.188	1.700
TOTAL	100,0	0.137	0.159	1.575

Notes:
(a) Energy consumption in Toe/value added in thousand Euros (median value)
(b) gross operating surplus/value added (median value)
(c) labour productivity over unit labour cost (median value)

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[21] See Tables A1 and A2 in the Appendix.

Mean factor and fuel cost shares are presented in Tables 2 and 3 respectively. While materials is the dominating cost share for all sectors with the highest value for low-tech manufacturing, it appears that energy represents the smallest cost share with the smallest value for medium-high tech firms in the panel. As regards the four energy inputs considered in this study, electricity is the dominating energy cost share for all activities while natural gas comes second. However, fuel cost shares do not show significant differences across technology sectors.

Table 2 – Cost Shares for the KLEM model (%)

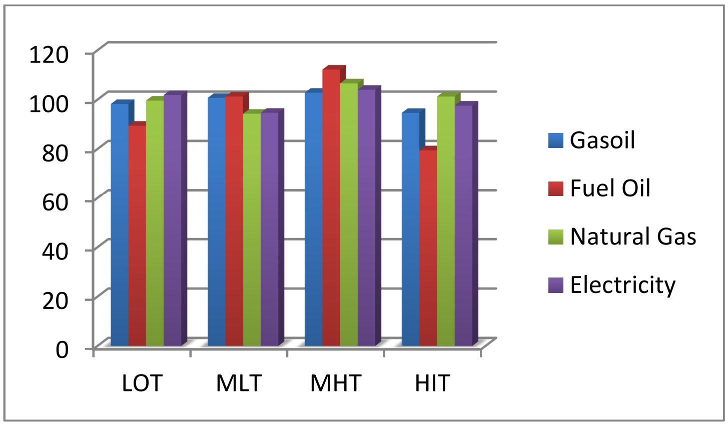
	LOT	**MLT**	**MHT**	**HIT**
share *(l)*	26.9	27.9	30.1	27.0
share *(m)*	62.0	57.5	61.2	61.1
share *(en)*	4.0	6.3	1.9	3.8
share *(k)*	7.1	8.3	6.8	8.1

Table 3 – Cost shares for the Energy sub-model (%)

	LOT	**MLT**	**MHT**	**HIT**
share *(g)*	9.3	6.4	8.6	7.5
share *(e)*	64.3	63.3	68.1	66.6
share *(f)*	2.3	1.7	1.2	2.1
share *(ng)*	23.8	28.0	21.3	23.5

Finally, price variability of energy inputs across sectors is represented in Figure 1. High tech industries show a below average unit price for all fuels with a significant variability of prices across sectors especially as regards fuel oil and electricity.

Figure 1 – Energy prices for manufacturing technological sectors (Average=100)



4. Estimation results and discussion

The factor demand system and the model for fuel demand are estimated for the period 2000-2005 over the panel of Italian firms classified in four sectors according to technological intensity. In order to avoid singularity, the capital equation in the factor demand system and the natural gas equation in the energy model are dropped.[22] Estimates of the omitted share equations are obtained from the homogeneity restrictions. Parameters are estimated using the seemingly unrelated regression technique (Zellner, 1962) which allows correlated errors between equations and GLS uses to estimate parameters in a more efficient way. Elasticities are then computed for the sample mean and standard errors are approximated by the delta method. Because our main interest is in interfactor and interfuel substitution, we report only estimated elasticities from the demand systems.[23] We note, however, that parameter estimates based on the micro panel are highly significant with small standard errors, thus suggesting that the elasticities estimated with firm-level data are much more robust than those obtained from time-series data.[24]

4.1 Own and cross-price elasticities

The panel estimation provides reasonable interfactor and interfuel elasticity values. Starting with production factors (Table 4), energy own price elasticity is always negative and statistically significant, whereas for capital, labour and materials estimated values cannot always be considered different from zero. With the exception of firms belonging to Low Technology sectors, energy demands show a considerable reactivity to price movement as the own price elasticities are negative and greater than one. Negative and significant values can be found also for capital (LOT and MLT), materials and labour (MLT). Medium High Technology and Low Technology show positive and significant values for labour demand, meaning that a rise in wages may be associated with a demand increase[25]: this positive link can be interpreted as an indication of wage efficiency, but given the difficulty of distinguishing between skilled and unskilled workers this is little more than an indication. Moreover, as shown in

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[22] Models are estimated with STATA econometric software.

[23] Tables containing parameters estimates of the factor and fuel models are available upon request.

[24] For instance, in the factor demand system if we consider the price coefficients of cost share equations, only 2 out of the total number of parameters are not statistically significant at least at the 1% critical level.

[25] This effect has also been found in Bardazzi et al. (2009) for larger firms.

Table 1, these two sectors exhibit the lowest cost competitiveness index. Cross price elasticities generally exhibit complementarity between energy and capital and substitutability between capital and labour and energy and labour. What is more, as a general finding, the sign of elasticity is homogenous between two factors (i.e. the sign is the same between capital-energy and energy-capital elasticities) though the magnitude is in some case noticeably different, depending on the factor whose price is moved.

Table 4 – Interfactor own and cross price elasticities

(Standard error in parentheses)

	Own price				Cross price elasticity					
	Energy	Capital	Labour	Materials	E/K	K/E	L/K	K/L	E/L	L/E
LOT	-0.898*** *(0.04)*	-0.881** *(0.34)*	0.039* *(0.02)*	0.070 *(0.04)*	0.187*** *(0.05)*	0.104*** *(0.03)*	0.159*** *(0.01)*	0.602*** *(0.05)*	0.382*** *(0.05)*	0.056*** *(0.01)*
MLT	-1.353*** *(0.04)*	-0.744* *(0.37)*	-0.198*** *(0.02)*	-0.190*** *(0.05)*	-0.137*** *(0.03)*	-0.103*** *(0.02)*	0.112*** *(0.01)*	0.377*** *(0.05)*	0.374*** *(0.04)*	0.083*** *(0.01)*
MHT	-1.136*** *(0.07)*	0.026 *(0.95)*	0.087*** *(0.02)*	0.061 *(0.11)*	-0.758*** *(0.10)*	-0.216*** *(0.03)*	0.067*** *(0.01)*	0.296*** *(0.05)*	0.532*** *(0.10)*	0.034*** *(0.01)*
HIT	-1.287*** *(0.09)*	-0.544 *(0.61)*	0.046 *(0.03)*	-0.032 *(0.08)*	-0.406*** *(0.08)*	-0.192*** *(0.04)*	0.128*** *(0.02)*	0.420*** *(0.07)*	0.322*** *(0.09)*	0.046*** *(0.01)*

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 4 shows a substitutability between energy and capital in the Low Technology sector, a complementarity in all other sectors and a generalized stronger effect of energy demand after a capital price change than in the case of capital demand after an energy price change. As discussed in paragraph 1.2, complementarity is a widespread result among estimations for European countries. As previously discussed, complementarity is a worrisome signal because capital can decrease after an energy costs increase; however a substitution of capital quality – towards energy saving technologies – cannot be excluded by data. Interestingly, this result is not confirmed in the Low Technology case, where energy intensity is high and the quality of capital appears much lower than in other sectors: for these firms there is more room for an increase in capital and the substitution process is evident after an energy price change. As prescribed by the theory, capital and labour are substitutes with a higher reactivity of capital to adjustment after a labour cost change. Obviously the relationship between labour and capital can also depend on the specialization of workers, and skilled workers are probably more likely to be complements with capital. Labour and energy (and labour and materials, not reported in the table) are also substitutes but the degree of substitutability is generally small.

Looking at the composition of energy costs, Table 5 shows own and cross elasticities for the main four fuels. All own fuel elasticities are negative and statistically significant, much higher for gasoil and fuel oil and lower in the case of the two main energy inputs, electricity and natural gas. In the case of electricity, the higher the level of the technology, from LOT to HIT, the lower the reactivity of fuel demand to price change. The vast majority of fuel combinations is statistically significant and exhibits substitutability. In any case the reaction of electricity and natural gas after changes of minor fuels is generally low, whereas the opposite is true for gasoil and fuel oil. It's worth mentioning that these two minor energy inputs are much more carbon intensive than electricity and natural gas and this is why price signals have been largely used, through pigouvian taxes, as a way of discouraging their use.

Table 5 – Interfuel own and cross price elasticities

(Standard error in parentheses)

	Own price				Cross price elasticity					
	Gasoil	Electricity	Fuel Oil	Nat. Gas	G/EE	EE/G	G/NG	NG/G	EE/NG	NG/EE
LOT	-0.735*** (0.04)	-0.561*** (0.02)	-1.147*** (0.07)	-0.561*** (0.02)	0.873*** (0.06)	0.122*** (0.01)	-0.032 (0.06)	-0.012 (0.02)	0.402*** (0.02)	1.037*** (0.05)
MLT	-0.864*** (0.10)	-0.530*** (0.02)	-1.931*** (0.14)	-0.530*** (0.02)	1.564*** (0.10)	0.165*** (0.01)	-0.563*** (0.09)	-0.173*** (0.03)	0.165*** (0.01)	0.763*** (0.04)
MHT	-1.074*** (0.04)	-0.417*** (0.02)	-1.199*** (0.08)	-1.699*** (0.14)	0.846*** (0.06)	0.107*** (0.01)	0.167*** (0.05)	0.063*** (0.02)	0.107*** (0.01)	0.063*** (0.02)
HIT	-1.867*** (0.08)	-0.299*** (0.03)	-1.699*** (0.14)	-0.843*** (0.05)	1.274*** (0.13)	0.113*** (0.01)	0.345*** (0.10)	0.074*** (0.02)	0.113*** (0.01)	0.501*** (0.05)

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

4.2 Morishima elasticities

Cross-price elasticities provide a simple measure of factor substitutability and all other standard substitution measures can be expressed in relation to this indicator. As argued by Frondel (2004, 2011) cross-price elasticities are, however, more intuitive as they may be termed a measure of absolute substitutability rather than being expressed in terms of input ratios such as the Morishima elasticities of substitution. In spite of their theoretical superiority (Blackorby and Russell, 1989), MES have been little used in empirical work for measuring input substitution until recent years, during which they have gained favour.

The estimates of cross-price elasticities presented above classify energy and capital as complements and, although empirical evidence on capital-energy elasticity has been rather mixed, this result may be reasonable in a multifactor production setting, where the behaviour of one input in reaction to a change of the price of another input will also depend upon the associated adjustments of other factors such as labour and material inputs. Indeed, Stern (2004) after applying several definitions of elasticities concludes that "capital and energy are at best weak substitutes and possibly are complements. The degree of complementarity likely varies across industries and the level of aggregation considered. However, if the cost share of energy is small relative to that of capital, only small percentage increases in capital will be needed for large percentage reductions in energy use" (p.29). If cross-price elasticities convey the information on whether inputs are substitutes or complements – in the sense of what the effect of a change in price of one factor is on the demand for another – and therefore represent an economic measure of substitution based upon actual changes, MES represent a technological substitution potential (Koetse et al., 2008). In particular, Morishima elasticity measures relative input adjustment to a single factor price change by holding other prices and output constant. Moreover, the input ratio reacts differently depending on which price is changing, thus asymmetry is implied. Instead of misusing MES to classify factors as complements or substitutes with respect to a change in price,[26] there are two elements on which Morishima elasticities can provide interesting insights. The first concerns changes in factor shares, while the second is related to the asymmetry of MES.

Following Blackorby and Russell (1989), the Morishima elasticity provides information about the percentage change in relative shares given by a percentage change in an input price:

$$\frac{\partial \log(s_i/s_j)}{\partial \log(p_j)} = MES_{ij} - 1$$

Therefore the share of input *i* relative to the share of input *j* increases – following an increase in p_j – only if MES_{ij} is greater than one. The degree of departure of the Morishima elasticity from unity provides immediate quantitative information about the effect on the relative factor shares and, consequently, about the difficulty in substitution: if firms can reduce their cost share on the factor whose price has increased then inputs are good substitutes for a fixed amount of output.

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[26] Indeed most inputs are found to be substitutes according to Morishima elasticities because the own price elasticity tends to be larger (in absolute value) than the cross-price elasticity.

The second issue relates to the intrinsic asymmetry of MES. In terms of our analysis, the asymmetric substitutability tells us which factor (or fuel) is easier to substitute for another following the change of the price of one of the two inputs. Several factors may produce the dominance of one substitutability relationship on the reverse: short-run vs. long-run effects, differences in durability of factor use and in price dynamics. For instance, Kim and Heo (2013) analyze the asymmetric MES-substitutability between energy and capital arguing that when the substitution of capital for energy after a change in the energy price dominates the reverse "we can safely say that capital purchases have contributed to the adoption of energy-saving technologies" (p.81). This effect reflects a long-run adjustment of capital stock to changes in energy prices given that capital stock in the short-run is fixed. On the other hand, the substitution of energy for capital derives from short-run responses as energy purchases adjust more rapidly to changes in the price of capital.

Interfactor substitution

Results of Morishima elasticities for technological sectors can be analyzed according to these two perspectives. MES between energy and capital and between energy and labour are shown in Figures 2 and 3 respectively. Detailed results for MES and their standard errors are presented in Table A3 in the Appendix. [27] Although according to cross-price elasticities energy and capital are mostly complements, MES are generally positive and statistically significant particularly in the case of MES_{KE}. Therefore we are in case b) described in Section 2 where $\eta_{ij}<0$ but, in absolute value, smaller than the own-price elasticity of factor j: inputs are MES-substitutes although they are classified as complements according to cross-price elasticity. For instance, according to equation (7) $MES_{KE}=\eta_{KE}-\eta_{EE}$ hence, for high-tech industries, $MES_{KE}=-0.2-(-1.3)=1.1$: a one percent increase in the price of energy leads to a 0.2 per cent reduction in the use of capital and a 1.3 reduction for energy use, with constant output. The only exception to these positive values is MES_{EK} for medium-high tech firms – although not statistically significant – where a 1 per cent increase of p_k reduces energy use more than capital demand even though the relative price of energy is lower: this result confirms the conclusion by Frondel and Schmidt (2002) who find that MES-complementarity occurs when the cost share is small (in this sector the energy cost share is 1.9%, see Table 2). In Medium-Low and High Technology sectors, Morishima elasticities between capital and energy are greater than one, thus one

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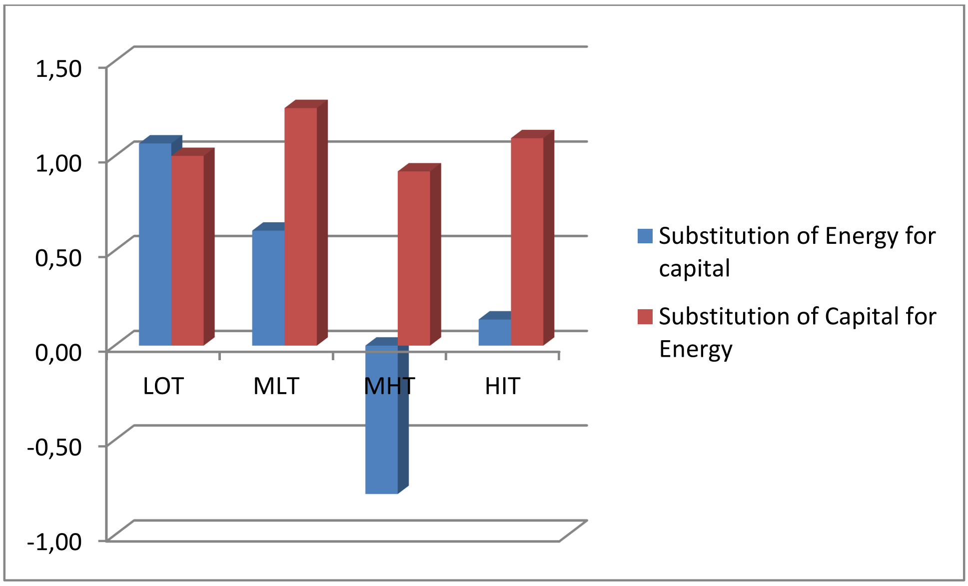
[27] MES are nonlinear functions of the estimated parameters and therefore standard errors for their estimates are approximated by delta method.

might argue that the share of capital would increase following a rise in energy price. However, in general, the potential substitution of capital for energy tends to dominate the reverse. This result may be explained by the high dynamics in energy prices in Italy, therefore firms have adjusted the characteristics of the capital stock to more energy-saving technologies in a long-run perspective despite the share of energy in total production costs being relatively small.

This finding is confirmed if the model is run across sectors according to firm size (Figure 4): for large enterprises MES-substitution of capital for energy is greater than unity and asymmetry is noticeable. Cost shares of capital and energy are 8 and 3 per cent respectively: one may argue that these shares are not arbitrary but functions of the production technology where capital and energy are complements according to their cross-price elasticities[28] but, in the sense of Morishima elasticity, they are potentially substitutes with a share of energy decreasing relative to the share of capital as energy prices rise.

Figure 2 – Morishima elasticities between energy and capital



Key: LOT Low technology, MLT Medium-low technology, MHT Medium-high technology, HIT High technology.

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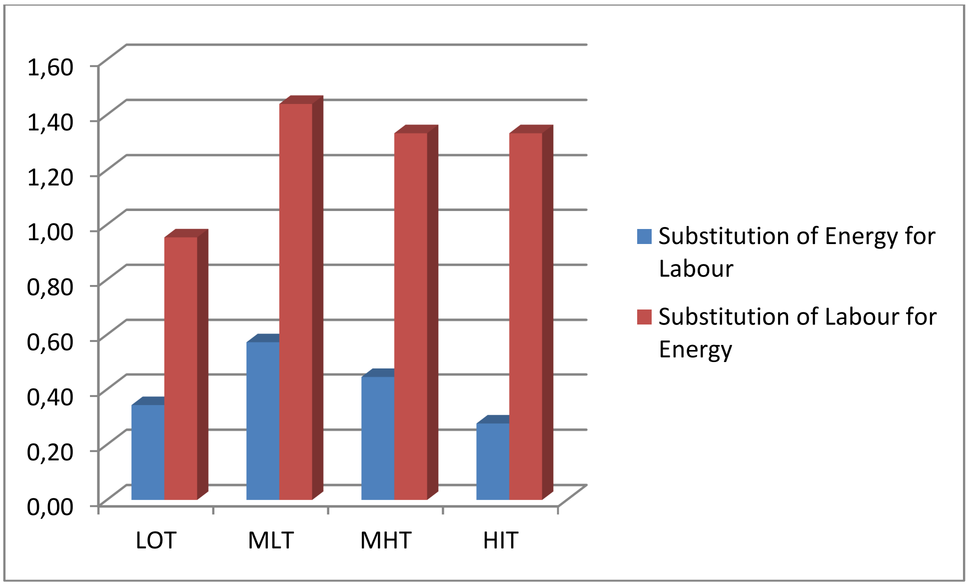
[28] The results for large firms are as follows: η_{ke} = -0.09 and η_{ke} = -0.19 which implies a reduction of capital purchases implied by an increase of energy prices.

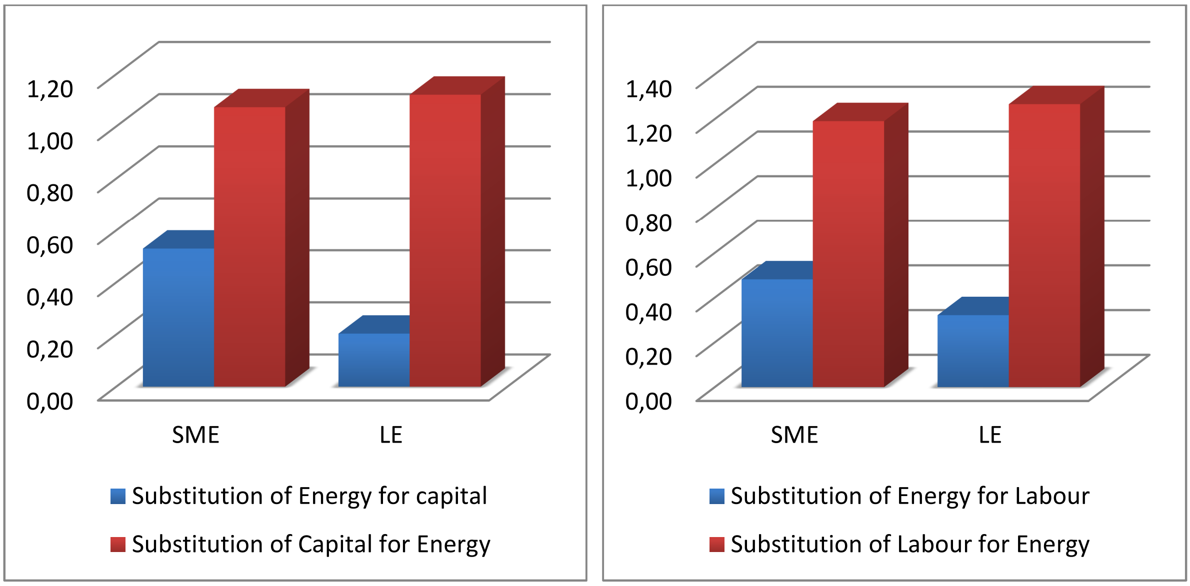
Figure 3 – Morishima elasticities between energy and labour



Key: LOT Low technology, MLT Medium-low technology, MHT Medium-high technology, HIT High technology.

As regards labour and energy, Figure 3 shows that these factors are MES-substitutes (as in terms of cross-price elasticities) and there is a significant asymmetry: MES_{LE} dominates the reverse with results greater than one for three sectors except LOT firms. These findings may be explained by the same arguments suggested above: labour and energy are good substitutes but it's easier to reduce the share of energy when energy prices increase than to reduce the labour cost share after a rise in labour prices. Indeed most workers are employed with open-end contracts and dismissal is strictly regulated, particularly for firms with more than 15 employees.[29]

Figure 4 - MES for Small-medium enterprises (SME) and Large enterprises (LE)



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[29] This difference in regulation may explain the slightly higher value of MES_{EL} for SMEs in Figure 4.

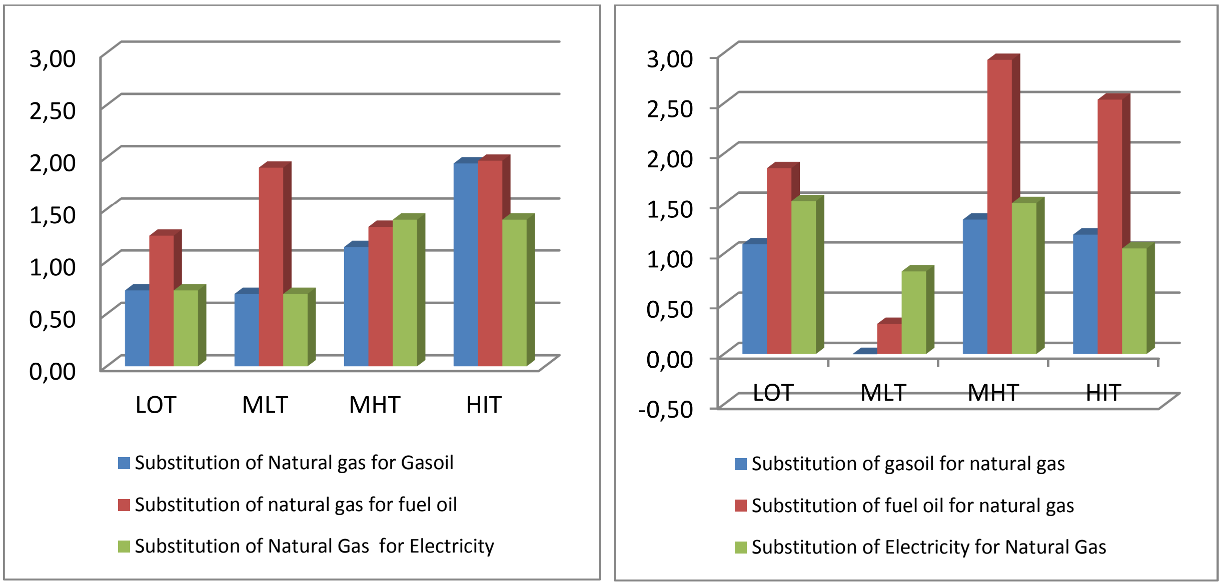
It would be useful to compare interfactor elasticities estimated here for the Italian manufacturing sector and its technological subsectors with the results from other studies on industrial factor and fuel demand in Italy. To the best of our knowledge, there have been no similar studies on Italian interfactor and interfuel substitution at the national level, in particular using a micro panel of industrial firms. However, more recently some international studies have been performed on time-series data for selected countries including Italy and the results of this study may be assessed in comparison with them. Medina et al. (2001) use aggregate data for the period 1980-1996 to investigate a three-factor (KLE) demand model for Italy, Portugal and Spain. Their results show complementarity between energy and capital both from cross-price and Allen elasticities while energy and labour are good substitutes. Morishima elasticities are computed by Kim and Heo (2013) on time-series data for the manufacturing sector of some OECD countries from 1980 to 2007. In this study energy and capital are divided into sub-inputs: electricity and fuel, capital increasing electricity demand – such as ICT assets – and capital stock not increasing electricity use -- such as transport equipment and non-residential structures--. Their results for Italy show that for both energy inputs MES_{EK} is positive, so electricity and fuel are substitutes for capital inputs with low values of Morishima elasticities ranging between 0.15 and 0.35. Although relatively low, these values dominate the elasticities of capital for energy, which contradicts our results as we conclude that appropriate energy pricing may promote energy-saving capital purchases. Many characteristics distinguish this study from Kim and Heo (2013) as regards model specification, aggregation of energy and capital input, time span and, above all, data type. As discussed in paragraph 1.1, all these factors may concur to explain conflicting results.

Interfuel substitution

Morishima elasticities between gasoil, electricity, fuel oil and natural gas are presented in Table A4 in the Appendix. Here we focus in particular on the substitutability of natural gas with respect to other energy sources. In Italy natural gas represents around 40% of total energy used by manufacturing according to 2012 data (National Energy Balance) being the largest share in terms of quantities followed by electricity (32 per cent). Moreover, the European Commission Energy Roadmap 2050 (EC, 2011) identifies natural gas as a transitional fuel for the transformation of the energy system toward a sustainable low-carbon economy. Therefore the potential substitution of fossil fuels with natural gas could help to reduce GHG emissions in the short to medium term.

Figure 5 shows Morishima elasticities between natural gas and the other energy sources considered in this study.

Figure 5 – MES for natural gas and other energy inputs



All MES are positive thus interfuel potential substitutability is estimated. For firms with medium-high and high technology intensity substitution of natural gas for other fuels is strong (greater than unity), hence the natural gas share is expected to increase following the increase of other energy prices. Therefore there is scope for identifying appropriate fiscal policies which can give an effective impulse in this direction by changing relative prices. Very high values are estimated for substitution between fuel oil and natural gas irrespective of the price change. Indeed fuel oil has the most elastic demand according estimated own-price elasticity and, although it represents the smallest energy cost share for firms in our panel, it is considered a very polluting energy input. Asymmetry of MES is noticeable especially for the relationship between natural gas and fuel oil with $MES_{OIL-NG} > MES_{NG-OIL}$. However, the reverse is true for the Medium-low Technology sector where potential substitutability is weak and lower when the natural gas price changes. It should be remembered that this sector includes several energy-intensive economic activities – fabrication of metal products, other non-metallic products, rubber and plastics – whose production processes are likely to be rather fixed from an engineering point of view.

Empirical evidence on interfuel substitution in Italy is very scarce. Morana (2000) estimates a model for oil, electricity, gas and coal for the Italian economy over the period 1978-1994 using quarterly OECD aggregate data as an application of a structural time-series approach. However, due to the different energy products selected in this study, his results are not fully comparable with our estimates. In general, Morana concludes that energy demand is not very responsive to price changes and therefore energy taxes would not be an effective way of influencing energy demand. More recently Serletis et al. (2009) investigate interfuel substitution for a set of countries including Italy for the period 1980-2006 with IEA aggregate data and a three-fuel model for industrial sectors (oil, coal and electricity). Morishima and own-price elasticities reported in this study show that demand is rather inelastic to price variation and there is a mild substitutability between energy input (MES<1) with limited asymmetry. The discussion in paragraph 1.2 may help to explain these undervalued elasticities based on aggregate data in both studies in comparison with our results obtained from firm-level data.

5. Conclusive remarks

The high energy dependency of the European Union forces policy makers to carefully consider various scenarios regarding energy security and price change effects on consumers and firms. A measurement of agents' reactivity is a key starting point for analyzing economic impacts and available policy options. A high elasticity for consumers and firms is, generally speaking, a positive outcome because it shows the ability of agents to change the energy mix and consequently to shift the burden and preserve disposable income and profits.

However, the use of empirical results for policy design should be very cautious as each approach implies specific limitations and a hierarchy of methodological approaches cannot be definitively established but must be based on the purpose of the analysis. We believe that a microeconometric analysis of firms' elasticities – thus taking energy products and firms' heterogeneity into account – is useful not only for the microeconometric approach per se, but also as an input for the macroeconomic and CGE models. The analysis of agents' heterogeneity is even more important in the Italian manufacturing industry case, which has a large variety of activity sectors (and therefore production functions) and is characterized by a very high variance of firm dimensions.

Notwithstanding a broad and long-lasting empirical literature on energy-related factors and fuel elasticities, as far as we know, empirical estimations for the Italian case are very rare and macro or sectoral analyses dominate. Using a KLEM translog function, this study provides empirical estimates of own and cross-price elasticities according to four categories of technological classification of manufacturing industries. The dataset is built on a panel of more than 2500 firms for which energy costs and balance sheet data are considered. As for input factors own price elasticities, negative and statistically significant values prevail for energy and capital, whereas labour also shows positive values. Looking at the capital-energy debate, cross-price elasticities also confirm for Italy a general complementarity between energy and capital and substitutability links between capital and labour and energy and labour. Substitutability between energy and capital is found, however, in the LOT category (Low Technology firms). As discussed in paragraph 1.2, a general complementarity between energy and capital is coherent with results found for other European countries using different kinds of models and methodologies (see Stern (2004) and Broadstock et al. (2007)). In the case of fuel mix, all own price elasticities are negative and statistically significant and a general substitutability link is found between electricity, natural gas and gasoil (with the exception of Medium Low technology sectors, where complementarity between electricity and gasoil is estimated). As a general finding, the two main fuel inputs, electricity and natural gas, exhibit lower elasticities, being more difficult to replace than the other inputs.

A special, in-depth analysis has been devoted to the estimation and discussion of Morishima elasticities. If cross-price elasticities represent an economic measure of substitution based on actual price changes, MES correspond more to a technological substitution potential (Koetse et al., 2008). In particular, as previously discussed, a positive sign of Morishima elasticity denoting factor substitutability is generally expected. This is confirmed by our empirical results both in interfactor and interfuel substitution. However additional informative content can be obtained by analysing the asymmetry of MES which is implicit in their definition. Indeed, in Medium-Low and High Technology sectors, MES between capital and energy are greater than one, thus the share of capital would increase following a rise in energy price. However, in general, the potential substitution of capital for energy tends to dominate the reverse. As energy prices in Italy are highly dynamic, one can argue that firms have adjusted the characteristics of their capital stock to more energy-saving technologies in a long-run perspective. Finally, applying the Morishima measure to interfuel substitution largely confirms the results of cross price elasticities. In particular for natural gas, as a transitional fuel for switching toward a sustainable low-carbon economy, MES are greater than unity with respect to other fuels, hence its share is expected to increase following an increase of other energy prices.

The main conclusion of this microeconometric analysis is that firms' behaviour in factors and fuels demand is reactive to relative price changes even in the short run which is the time framework considered in this empirical study. Therefore appropriate fiscal policies could be designed to give an effective impulse by changing relative prices for energy-saving and environmentally-friendly input mixes.

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APPENDIX

Table A1 - Manufacturing industries classified according to their global technological intensity

LOT - Low technology manufacturing	**NACE Revision 1.1**
- Food products, beverages and tobacco	15, 16
- Textiles	17
- Wearing apparel	18
- Luggage, handbags, and footwear	19
- Wood, except furniture	20
- Pulp, paper and paper products	21
- Publishing, printing and reproduction of recorded media	22
- Furniture; manufacturing n.e.c.	36
MLT - Medium-low technology manufacturing	
- Rubber and plastic products	25
- Other non-metallic mineral products	26
- Basic metals	27
- Fabricated metal products, except machinery and equipment	28
MHT - Medium-high technology manufacturing	
- Machinery and equipment n.e.c.	29
- Electrical machinery and apparatus n.e.c.	31
- Motor vehicles, trailers and semi-trailers	34
- Other transport equipment	35
HIT - High technology manufacturing	
- Chemicals and chemical products	24
- Office machinery and computers	30
- Radio, television and communication equipment	32
- Medical, precision and optical instruments	33

Table A2 – Number of firms in the panel

High-tech classification of manufacturing industries	year					
	2000	2001	2002	2003	2004	2005
LOT Low technology	965	962	970	976	894	918
MLT Medium-low technology	844	821	810	805	772	772
MHT Medium-high technology	678	648	662	671	637	638
HIT High technology	309	303	300	320	282	300
TOTAL	2796	2734	2742	2772	2585	2628

Table A3 – Interfactor Morishima Elasticities

	LOT	MLT	MHT	HIT
MES_{LM}	-0.324*** *(0.05)*	0.193** *(0.06)*	-0.249* *(0.11)*	-0.188 *(0.10)*
MES_{LE}	0.954*** *(0.04)*	1.436*** *(0.04)*	1.170*** *(0.07)*	1.333*** *(0.09)*
MES_{LK}	1.040** *(0.34)*	0.856* *(0.37)*	0.041 *(0.95)*	0.671 *(0.61)*
MES_{ML}	-0.150*** *(0.03)*	0.200*** *(0.03)*	-0.179*** *(0.03)*	-0.142** *(0.04)*
MES_{ME}	0.919*** *(0.05)*	1.474*** *(0.04)*	1.178*** *(0.07)*	1.373*** *(0.10)*
MES_{MK}	0.901* *(0.38)*	0.812 *(0.42)*	-0.038 *(1.05)*	0.586 *(0.69)*
MES_{EL}	0.343*** *(0.06)*	0.572*** *(0.04)*	0.445*** *(0.11)*	0.277** *(0.10)*
MES_{EM}	0.259** *(0.10)*	1.306*** *(0.09)*	1.300*** *(0.20)*	1.403*** *(0.19)*
MES_{EK}	1.067** *(0.35)*	0.607 *(0.37)*	-0.784 *(0.96)*	0.137 *(0.61)*
MES_{KL}	0.563*** *(0.05)*	0.575*** *(0.05)*	0.209*** *(0.06)*	0.374*** *(0.08)*
MES_{KM}	0.105 *(0.38)*	0.660 *(0.42)*	-0.167 *(1.05)*	0.348 *(0.68)*
MES_{KE}	1.001*** *(0.05)*	1.250*** *(0.04)*	0.920*** *(0.08)*	1.095*** *(0.10)*

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table A4 – Interfuel Morishima Elasticities

	LOT	MLT	MHT	HIT
$MES_{G\text{-}EL}$	1.433*** *(0.07)*	2.095*** *(0.11)*	1.262*** *(0.07)*	1.574*** *(0.15)*
$MES_{G\text{-}F}$	1.042*** *(0.07)*	1.793*** *(0.16)*	1.261*** *(0.08)*	1.947*** *(0.17)*
$MES_{G\text{-}NG}$	1.091*** *(0.10)*	-0.003 *(0.12)*	1.342*** *(0.08)*	1.187*** *(0.11)*
$MES_{EL\text{-}G}$	0.857*** *(0.04)*	1.029*** *(0.10)*	1.182*** *(0.05)*	1.980*** *(0.09)*
$MES_{EL\text{-}F}$	1.184*** *(0.07)*	2.034*** *(0.15)*	1.178*** *(0.08)*	1.678*** *(0.15)*
$MES_{EL\text{-}NG}$	1.525*** *(0.08)*	0.821*** *(0.06)*	1.506*** *(0.06)*	1.050*** *(0.07)*
$MES_{F\text{-}G}$	0.453*** *(0.08)*	0.503** *(0.17)*	1.385*** *(0.10)*	2.202*** *(0.13)*
$MES_{F\text{-}EL}$	1.260*** *(0.13)*	3.082*** *(0.20)*	-0.449* *(0.18)*	-0.029 *(0.22)*
$MES_{F\text{-}NG}$	1.853*** *(0.15)*	0.300 *(0.19)*	2.930*** *(0.19)*	2.535*** *(0.17)*
$MES_{NG\text{-}G}$	0.724*** *(0.05)*	0.690*** *(0.11)*	1.137*** *(0.05)*	1.941*** *(0.09)*
$MES_{NG\text{-}EL}$	1.598*** *(0.08)*	1.294*** *(0.05)*	1.398*** *(0.06)*	0.800*** *(0.08)*
$MES_{NG\text{-}F}$	1.246*** *(0.07)*	1.900*** *(0.15)*	1.330*** *(0.09)*	1.967*** *(0.15)*

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Key: G, gasoil; EL, electricity; F, fuel oil; NG, natural gas.