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Measuring the Energy Input Substitution and Output Effects of Energy Price Changes and the Implications for the Environment.

Akinsehinwa Sharimakin[a,b]

Abstract

Previous studies of decomposition of factor inputs have limited their analysis on the estimation of substitution and output effects. However, this paper develops a two-step approach to estimate the substitution and output effects of changes in energy demand resulting from changes in prices and further examines the implications of these effects on CO_2 emissions using European industrial dataset over the period 1995-2007. In our empirical estimations, instead of relying only on iSUR model like previous studies, we introduced a multilevel model, which is a more befitting model to our data. Our analysis covers industry as a whole and for different sector types. The primary results emerged from our analysis suggest a strong evidence using the multilevel model. Generally, our results show that production inputs are substitutable. We find the substitution and output effects to be negatively related to CO_2 emissions, however, the substitution effects dominate. From policy perspectives, our results suggest that output adjustments may not play a significant role in reducing emissions. We find the overall effects of changes in energy demand to be moderate. Then, we argue that increment in energy taxes should be complemented by cleaner factor substitution and sustainable growth to achieve a desirable carbon reduction.

Key words: European industries; Substitution elasticities; Decomposition effects; Carbon emissions.

JEL classification:
C3
D22
Q41

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1 Introduction

The oil price shocks and subsequently the growing awareness about the increasing greenhouse gases have initiated serious concern about energy security and environmental degradation. In particular, CO_2 emission is one of the major environmental threats as it accounts for almost half of the anthropogenic greenhouse gases (Floros and Vlachou, 2005). On the other hand, technological improvement in terms of energy-savings is considered as an important way of mitigating greenhouse gases. Hence, reduces the sensitivity of consumers to increase in energy prices.

For instance, in production setting, the substitution of non-energy input for energy input can be characterised as a way of energy-savings or improvement in energy efficiency[1]. The positive implications of substituting non-energy input for energy input can be categorised into two folds. Firstly, it removes over-reliance of continuing increase in energy prices as a way of stimulating improvement in energy efficiency. Secondly, it is a way of reducing the pressure of increasing global energy consumption and thus, regarded as a natural way of reducing greenhouse gases with some social environmental benefits. Therefore, one can argue that the primary motive behind capital-energy substitution is to reduce energy consumption and consequently, improving environmental quality via reduction in anthropogenic greenhouse gases.

In fairness, empirical investigation of the substitution possibilities among factor inputs in the literature is well documented. In fact, the elasticity of substitution among production inputs plays an important role in firm's decision making when the price of an input changes. In production settings, this allows a representative producer to adjust inputs demand and minimise cost by purchasing more of less expensive inputs to cover for the more expensive

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[1] However, a range of mechanisms, commonly grouped under the heading of rebound effects may reduce the size of the 'energy savings achieved.

input(s). However, the elasticity of substitution does not provide a complete picture of inputs adjustment resulting from a relative change in input prices. This is because the pure elasticity of substitution assumes that the producer's output is constant over time whereas in reality, producers consistently adjust output in response to changes in relative factor prices and market conditions. Chambers (1982) argues that the output effect represents a more complex picture of inputs adjustments within a production function compared to the substitution elasticities because the output effect takes account of the fact that producers are not operating under the assumption of constant or given level of output unlike the substitution elasticities. Given the connection between changes in factor price and the producer's reaction to these changes, therefore, an empirical assessment of both the substitution and output effects of changes in factor price would provide a more complex picture of inputs adjustment.

This paper adopts a two-stage procedure by firstly presents a decomposition analysis of changes in energy demand resulting from changes in price and in the second stage, investigates the implications of the decomposition effects on CO_2 emissions using industry level data for a sample of European countries for the period 1995 – 2007. In particular, we explored the substitution possibilities between energy and other factors under the assumption of constant level of output. We then relax the assumption of constant level of output with decomposing the derived energy demand into substitution effect and output effect, and then empirically examine the impact of the substitution and output effects alongside other competing factors on carbon emissions.

Arguably, we could present the reaction of a representative producer to changes in energy prices in terms of input substitution and output adjustment as the producer is expected to reduce energy consumption as energy price increases. This is achievable by altering production system through the substitution of other factor inputs for energy, if substitution is possible, which is termed as pure technical substitution adjustment. However, in reality, an increase in energy prices would not only lead to inputs demand substitution, but also output adjustments as producer is expected to adjust output accordingly in response to relative changes in input price. For instance, if the price of an input increases, the expectation is that the total cost of the producer will also rise. Similarly, substitution possibility between inputs allows producers to minimise cost by consuming more of those inputs that are relatively cheap and less of that input(s) with higher price(s). This implies that the producer's cost of production is affected by the elasticity of substitution between factor inputs.

The process of input adjustment can increase the total cost of the producer or leaves the producer at the same cost before the increase in price. For instance, if substitution between energy and non-energy is very strong, then a relative increase in energy price to other inputs' prices may not affect the cost of the producer as the producer can easily alter their inputs by using more of non-energy inputs that are relatively cheaper. However, if substitution possibility between inputs is weak, then a relative increase in factor price is very likely to increase the cost of the producer, which might force such producer to cut down production (output adjustment).

Despite the shortcoming associated with the elasticity of substitution among production factors, it remains an interesting research area in the academic literature. This is because the elasticity of substitution provides insightful information about the likely effect of relative changes in factor prices and relevant to policy questions related to the management of demand and supply for factor inputs (Kotse et al., 2008). Since the seminar work of Berndt and Wood (1975), the substitutability between capital and energy remained a subject of controversy as one strand in the literature suggests that energy and capital are substitutes, while another strand suggests they are complements. Berndt and Wood (1975) employ the translog model initially proposed by Christensen et al. (1973) to investigate the possibility of factor substitution and find capital and energy as complements. This argument is reinforced in

Fuss (1977), Anderson (1981), Prywes (1986), Arnberg and BjØner (2007), and Tovas and Iglesias (2013). However, another strand in the literature refuted the claim that energy and capital are complements by arguing that they are actually substitutes. Among others, Cameron and Schwartz (1979), Uri (1982), Viñals (1984) and Truong (1985) find energy and non-energy inputs as substitutes. More recently, Kim and Heo (2013), Haller and Hyland (2014), and Lin and Ahmad (2016) investigate the substitution possibility between energy and other inputs, and they find that energy and other production factors are substitutes.

The above arguments imply that there is no consensus in the literature about the substitution possibilities between energy and other factor inputs. Ironically, the inconclusive evidence about the substitutability between capital and energy makes it a popular research area in academic literature. Notwithstanding the popularity of the elasticity of substitution between production factors, the fact remains that it fails to provide a complete picture of input adjustments as it ignores the output effect of changes in relative input prices. From consumers' perspectives, Ashenfelter and Heckman (1974) build on the theory of consumer behaviour to analyse the income and substitution effects of negative income tax for US household labour supply.

A more connected work to this study is Kako (1978) where the author analysed the growth of rice production in Japan by decomposed labour input demand into output effect, factor substitution effect and technical effect. The author finds technical change as the main reason why labour input declines and that the labour-saving effect from factor substitution are relatively small compared to the output effect. Chambers (1982) presents the theoretical and empirical exposition of the importance of output effects of changes in relative input prices by demonstrating how to use estimates of dual cost functions to generate the compensated and uncompensated elasticities. The author finds only capital and materials as complements when considering the pure substitution effect. However, materials and all other inputs are complements, when the level of output is free to adjust in response to changes in factor price. The author further highlights the importance of the output effect in terms of the difference between the compensated and uncompensated elasticities. More recently, Adetutu et al. (2016) empirically investigate the substitution and output effects of changes in energy input demand for the individual BRIIC countries. Their findings suggest that the substitution effect dominates the output effect in the BRIIC countries with estimated elasticities ranged from –0.007 to –0.020 for the period under consideration.

With respect to mitigation of carbon emissions, Enevoldsen et al. (2007) estimated translog production model to investigate the impact of energy prices and taxes on energy efficiency and CO_2 emissions of ten industrial sectors in Denmark, Norway and Sweden. Their main results suggest that energy taxes and more importantly carbon taxes would be important instruments to stimulate improvement in energy efficiency and reduction in carbon emissions. Tan et al. (2011) investigate the driving forces of China's carbon intensity for the period 1998-2008. The authors decomposed emission intensity to capture the effects of various fuels and found that energy intensity is the key to carbon reduction as it accounts for about 94% reduction in CO_2 emissions. These findings are similar to that of Chang and Lahr (2016).

Based on decomposition of energy share equation derived from a translog cost model, Li and Lin (2016) claim that China's carbon intensity decreased by 60.1% between 1986 and 2012 because of factor substitution, which mainly results from the substitution of labour for energy and technical progress. These findings are reinforced in Liu et al. (2018) having followed the same methodology employed by Li and Lin (2016). The findings from Liu et al. (2018) reveal that reduction in energy intensity in the form of capital-energy and labour-energy substitution is the key to emission reduction. Lin and Ahmad (2016) estimated a translog production function for Pakistan transport sector to find out the impact of factor substitution on carbon emissions for the sample period 1980-2013. The authors acknowledge the potential environmental damage the growing transport sector could leave behind and suggest that by allocating more capital in the transport sector, the relevant energy saving technology could be promoted via capital-energy substitution and consequently lead to a reduction in CO_2 emissions.

In a similar study, Liu and Lin (2017) estimated translog cost function to examine the substitutability of non-energy inputs for energy and its effect on CO_2 emissions for the China's building construction industry. Having analysed pooled data for different regions over the sample period 2003-2012, their findings reveal that energy and non-energy are substitutes whereas individual energy are complementary. Further, they suggest that increased in energy use and scale output expansion lead to energy efficiency improvement, and about 3% of the CO_2 emissions reduction in China's construction industry can be reduced by carbon tax. The work of Hao and Huang (2018) takes a different approach as the authors investigate the relationship between energy use structure and emissions per capita using a translog model. They suggest that by substituting oil or gas for coal could decrease carbon emissions significantly, but the substitution of gas for coal would yield an optimal result.

This paper contributes/different to the existing literature in two major ways. First, so far, research on the decomposition analysis of derived energy demand into substitution and output effects that is theoretically rooted like this study is relatively scarce. Second, the approach adopted in this paper offers further improvement on the existing literature by clearly indicating not only the impact of substituting non-energy for energy (substitution effect) on CO2 emissions, but also the impact of output effect on CO2 emissions. Unlike existing studies discussed above on the substitutability between energy and non-energy and/or the relationship between energy and CO2 emissions, this paper predominantly differs by decomposing changes in energy demand arising from increase in energy price into substitution and output effects using Slutsky equation. Subsequently, carried out an exploratory analysis to examine the impact of both the substitution and output effects taken into account of other competing forces on carbon emissions. In this paper, we performed an empirical analysis for the industry as a whole and for different sector types - primary, manufacturing and service sectors. From a policy point of view, we believe that the categorisation of the entire industries into different sector types would assist in formulating sector's specific energy/climate change policies as we expect our results to provide insightful information about different production technology.

The remainder of this paper proceeds as follows. In section 2, we outline the theoretical and econometric models used for the analysis. In section 3, we describe the dataset and provide summary statistics. Section 4 consists of two parts. In the first part, we present the elasticities of substitution among factors and that of the decomposition effect. In the second part, we analyse the impact of the decomposition effect with other competing factor on carbon emissions. In Section 5, we provide the concluding remarks and suggest possible further research.

2 Empirical Method

2.1 Modelling Framework: Translog Cost Function

Under the assumption of perfectively competitive markets for inputs, a standard cost minimization function can be written as follows:

$$c(y,p) \equiv \min_{z}\{p \cdot z\}\; s.t.\; y = h(z_1, \dots, z_x, A) \tag{1}$$

where z's represent capital, energy, labour and material. $p \in \mathbb{R}$ is the set of X input prices (i.e. p_k, p_l, p_e, p_m), y is output and $c = \sum_{x=1}^{X} p_x z_x$ is the total expenditure on inputs. To investigate the substitution possibility between production factors, we employ the translog cost model among available functional forms such as Cobb Douglas, Leontief and CES. Our modelling choice is motivated by the fact that the translog cost function remains as the most popular in the academic literature since its introduction by Christensen et al. (1973) due to its flexible nature, which limits any a priori restriction on factor inputs relationships[2]. Our translog cost function which is derived from the general functional form Eq. (1) is therefore specified as follows:

$$\begin{aligned}\ln C_{ijt} &= \alpha_0 + \alpha_y \ln y_{ijt} + \frac{1}{2}\alpha_{yy} \ln y_{ijt}^2 + \sum_{z=i}^{4} \delta_z \ln y_{ijt} \ln p_{z,ijt} + \sum_{z=1}^{4} \alpha_z \ln p_{z,ijt} \\ &+ \frac{1}{2}\sum_{z=1}^{4}\sum_{f=1}^{4} \beta_{zf} \ln p_{z,ijt} \ln p_{z,ijt} + \alpha_t t + \frac{1}{2}\alpha_{tt} t^2 + \alpha_{yt} \ln y_{ijt}\, t \\ &+ \sum_{z=1}^{3} \varphi_z \ln p_{z,ijt} t + v_{it} \qquad (2)\end{aligned}$$

where all variables remain as previously defined. ln denotes the natural log; i represents industries; t is time trend which captures technical progress; v_{it} is the residual. Our translog model allows for non-neutral technical change and non-constant return to scale in order to capture the role of economies of scale and technical progress within the production settings. Further, our translog model imposes the fundamental restriction of symmetry ($\beta_{zf} = \beta_{fz} \forall z, r$) and linear homogeneity ($\sum_i \alpha_i = 1; \sum_i \delta_i = \sum_i \varphi_i = 0\,; \sum_i \beta_{zf} = \sum_f \beta_{fz} = 0$) in the input prices. The fundamental homogeneity restriction allows us to normalise the cost and input prices with the price of material (p_m). We defined the normalised input prices as $\left(\frac{p_z}{p_m} = w\right)$.

In addition, unlike previous studies, in our empirical analysis we recognise the fact that industries are not operating in isolation as their activities are clearly interrelated with the

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[2] Other studies that have also used tranlog cost model include Lin and Ahmad (2016), Morakinyo et al. (2016), Lin and Lin (2017) and Liu et al. (2018).

activities of economy as a whole. In this regard, we control for the interactions between the industries and the economy by incorporating country level variables together with their interactions with the industry level variables in our translog cost function. Furthermore, we understand that the characteristics and activities of the sampled industries are not homogenous. As a result, we control for the heterogeneity across the industries by mean-adjusted all industry level variables to at least account for a minimum level of heterogeneity across sampled industries. We further account for industries heterogeneity by including a categorical variable to classify industries based on similarity in production activity (that is, primary, manufacturing or service sectors). Again, we include a dummy variable with “1” for industries with a multiple production unit and “0” for industries with a single production unit. The categorical and dummy variables are in our translog model as π_t. In addition, we account for the country-specific effects, by adding countries dummies (z_t) into our translog cost function. We incorporate all the above information into Eq. (2) and redefined it as follows:

$$
\begin{aligned}
\ln \frac{C_{ijt}}{p_{m,ijt}} = {} & \alpha_0 + \alpha_y \ln y_{ijt} + \frac{1}{2}\alpha_{yy} \ln y_{ijt}^2 + \sum_{z=i}^{3} \delta_z \ln y_{ijt} \ln w_{z,ijt} + \sum_{z=1}^{3} \alpha_z \ln w_{z,ijt} \\
& + \frac{1}{2}\sum_{z=1}^{3}\sum_{f=1}^{3} \beta_{zf} \ln w_{z,ijt} \ln w_{z,ijt} + \alpha_t t + \frac{1}{2}\alpha_{tt} t^2 + \alpha_{yt} \ln y_{ijt}\, t \\
& + \sum_{z=1}^{3} \varphi_z \ln w_{z,ijt} t + \alpha_Y \ln Y_{jt} + \alpha_{yY} \ln y_{ijt} \ln Y_{jt} + \sum_{z=1}^{3} \alpha_{zY} \ln w_{z,ijt} \ln Y_{jt} \\
& + \alpha_{tY} \ln Y_{jt}\, t + \sum_{r=1}^{4} \alpha_r \ln W_{r,jt} + \sum_{r=1}^{4} \alpha_{yW} \ln y_{ijt} \ln W_{r,jt} \\
& + \frac{1}{2}\sum_{z=1}^{3}\sum_{r=1}^{4} \beta_{rz} \ln w_{z,ijt} \ln W_{r,jt} + \sum_{r=1}^{4} \alpha_{tW} \ln W_{r,jt}\, t + \pi_t + z_t + v_{it} \qquad (3)
\end{aligned}
$$

where $z = k, l, e$; $r = k, l, e, m$; lower- and upper-case letters represent industry-level and country-level variables respectively. Y is the output at country level; W is the input prices at country level and other variables remain as previously defined. The cost minimising input demand function can be derived using Shepherd lemma by differentiating Eq. (3) with respect to factor input and this gives the input demand function in terms of cost share equations as:

$$S^{*}_{z,ijt} = \alpha_z + \varphi_z t + \sum_{f=1}^{3} \beta_{zf} \ln w_{z,ijt} + \delta_z \ln y_{i,j,t} + \alpha_{zY} \ln Y_{jt} + \sum_{r=1}^{4} \beta_{rz} \ln w_{r,jt} + \lambda_{it} \qquad (4)$$

where *S* is the factor share equation of *zth* input, is the error term and other variables remain as previously defined. Eqs. (3) and (4) can be jointly estimated using the popular Zellner's iterated seemingly unrelated regression (iSUR) technique given its ability to increase efficiency by controlling for potential correlation of the error terms across the cost share equations. However, given the hierarchical structure of our data where industries nested in countries over time, and the potential cluster-level heterogeneity usually associated with hierarchical data, it is very likely that the iSUR technique may produce unreliable estimates[3].

In addition, it is worth noting that the inclusion of the country level variables and their interactions suggest a necessity to account for the country level residual, which might not be possible with the iSUR[4]. In order to account for the hierarchical structure of the data as well as controlling for potential cluster-level heterogeneity, we therefore also estimate the cost function with a multilevel modelling. Multilevel modelling is a maximum likelihood estimation that aims to model the relationship between a response variable and a set of explanatory variables, but differs from standard regression analysis by modelling units of observation at different 'levels'. As noted in Sharimakin et al. (2018), multilevel modelling is predominantly for modelling hierarchical datasets, as the model possesses the ability to disentangle the clustering at different levels by including a disturbance term at each level of

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[3] Steenbergen and Jones (2002) discuss the statistical problems and consequences inherent in hierarchical data and demonstrate that failure to control for the hierarchical structure of the data will lead to biased and inconsistent estimates.

[4] The inclusion of both explanatory variables and error term at each level enables us to measure the unexplained heterogeneity associated with each level.

the data.[5] Unlike the iSUR, multilevel modelling is not an approach purposely meant to jointly estimate a system of equations as it requires the estimation of only Eq. (3), but its ability to control for the hierarchical structure of the data and cluster-level heterogeneity is a significant advantage[6]. Moreover, it allows us to introduce a model that incorporates the structure of our data.

On the other hand, Berndt and Christensen (1973) noted a notable shortcoming that might be associated with the use of single-equation models such as multilevel modelling and OLS if employ to estimate a system of equations like the translog cost function. The author argues that since such modelling techniques would relax the restrictions imposed on the translog cost function and thus, only estimate Eq. (3) as in our own case, without simultaneously estimating the cost share equations (4), then the validity of such translog cost function could be violated and needs to be verified. However, Barten (1969) investigate the properties of maximum likelihood and that of translog equations and concludes that there is no difference between their estimates. Kmenta and Gilbert (1968); Dhrymes (1971) support this claim as noted by Berndt and Christensen (1973) by demonstrate that the iSUR and the maximum likelihood estimators are computationally equivalent. Notwithstanding, the arguments by Barten (1969); Kmenta and Gilbert (1968); Dhrymes (1971) we responded to the potential shortcoming noted by Berndt and Christensen (1973) by also verified the validity of our translog cost function with the iSUR technique. As a result, we estimated our translog cost function with both estimation techniques.

Given that our data is considered as three-level hierarchical dataset where the number of observations is regarded as a level 1, the industries being regarded as level 2, which are nested in countries, that is, level 3, we estimated Eq. (3) with a three-level multilevel model.

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[5] For interested readers on multilevel modelling see Rabe-Hesketh and Skrondal (2012) and Hox et al. (2010).

[6] This means $\pi_t = z_t = 0$ while estimating Eq. (3) with a multilevel model.

In the case of multilevel model, we control for potential cluster-level heterogeneity in our dataset by redefined the error term in Eq. (3) as follows: $v_{ij} = u_j^{(3)} + u_{ij}^{(2)} + \epsilon_{ijt}$.[7] Where $u_j^{(3)}$ is the random term for the *j*th country, $u_{ij}^{(2)}$ denotes the nested effect of *i*th industry within the *j*th country, and ϵ_{ijt} is the remaining disturbance term for each observation in the sample.

2.2 Elasticities of Substitution

The elasticity of substitution (ES) between energy and non-energy inputs can be computed using the estimated parameters from the cost function Eq. (3) and the predicted cost shares Eq. (4). We apply the three most popular methods of measuring the elasticity of substitution in the literature, that is, the Allen-Uzawa elasticity of substitution (AES), cross-price elasticity (CPE) and the Morishima elasticity of substitution (MES). Although, each of these elasticities of substitution has unique features, but they are interrelated as both the CPE and the MES could be derived from the AES[8]. Allen (1934 and 1938) initially proposed the AES, and then Uzawa (1962) later demonstrated the empirical estimation of the AES from a fitted cost function. The AES is a partial elasticity as it measures the change in input *K* if the price of input *E* changes. For simplicity purposes, we refer to only inputs *K* and *E* when presenting our elasticities of substitution and the decomposition effects (when necessary). The formula for the AES is written as follows:

$$\sigma_{EE}^{AES} = \frac{\beta_{EE} + S_E^2 - S_E}{S_E^2}; \qquad \sigma_{EK}^{AES} = \frac{\beta_{EK} + S_E S_K}{S_E S_K} \tag{5}$$

where S_E and S_K are the estimated factor shares for energy and capital respectively and βs are the parameter estimates from the translog cost function. The AES considers inputs as complements if, $\sigma < 0$ and inputs as substitutes if, $\sigma > 1$. The main argument against the use of AES in the literature is the fact that it fails to provide information on relative factor shares

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[7] That is $v_{ij} = \epsilon_{ijt}$ while estimating Eq. (3) with iSUR.

[8] Broadstock et al. (2007) provide a detail explanation on the relationship between the AES, CPE and MES.

since the impact is on actual price changes rather than relative price changes. Blackorby and Russell (1981) argued that the symmetric nature of the AES (i.e.,σ_{EK}=σ_{KE}) makes it a limited measure of ES as it fails to capture the curvature properties of the production function. Although, the CPE and AES have similar features as both measure absolute change in input demand rather than relative change, but unlike the AES the CPE is asymmetric, that is, $\sigma_{EK} \neq \sigma_{EK}$. The asymmetric property of the CPE is therefore an added advantage. The CPE is written in terms of the AES as follows:

$$\eta_{EE} = s_E \sigma_{EE}^{AES}; \quad \eta_{EK} = s_K \sigma_{EK}^{AES}. \tag{6}$$

where η_{EE} is the own-price elasticity of energy input and η_{EK} is the cross-price elasticity between capital and energy. Given the shortcomings associated with AES and CPE, Blackorby and Russell (1981) proposed the use of MES as a more appropriate measure of ES. They argued that the MES is theoretically superior to the AES and CPE as it is closer to the original definition of ES proposed by Hicks (1932) as noted in Haller and Hyland (2014)[9]. Moreover, MES also allows for the evaluation of the elasticity of change in input ratios with respect to price ratios for a given level of output (Stern, 2011). The MES can be written in terms of the AES as:

$$\sigma_{EK}^{MES} = s_K(\sigma_{EK}^{AES} - \sigma_{KK}^{AES}). \tag{7}$$

where all notations remained as previously defined. The MES measures the change in the ratio of two inputs (*E/K*) when the price of *K* changes. If an increase in the price of *K* stimulates an increase in *E/K* input ratio ($\sigma_{EK}^{MES} > 0$) then *E* and *K* are substitutes. In other hand, if $\sigma_{EK}^{MES} < 0$ where an increase in the price of *K* reduces *E/K* input ratio, then *E* and *K* are complements. Unlike the AES the MES is asymmetric in nature ($\sigma_{EK}^{MES} \neq \sigma_{KE}^{MES}$) depending on which input price changes.

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[9] However, Frondel (2004) argues that the CPE is preferable on the basis that it is more applicable in practice given the fact that it is an absolute measure of ES rather than relative measures of ES.

2.3 Energy Demand Decomposition Effect

To this point, we mainly focused on the substitution possibilities among factors if the price of input changes by assuming that output level in unchanged. To recap, Chambers (1982) argues that these substitution elasticities do not represent the true characteristics of a cost minimising firm as it fails to account for the output effects of a change in input price. In other words, producers do not adjust their output as factor prices change. However, in principle, this assumption undermines the true nature of firm behaviour because in practice, producers adjust output not only to changes in factor price, but also to changes in technology, external shocks and e.t.c. Therefore, the output effect is important because it provides the missing point in input adjustments as factor price changes and represents a more complete picture of input adjustment than the elasticities of substitution derived from the estimated cost function.

To measure the reaction of a representative firm to changes in energy prices we use the Slutsky equation in microeconomic theory to decompose (substitution and output effects) changes in derived energy demand. Specifically, our interest is own-decomposition of derived energy demand to changes in own-price. To do so, we draw on duality theory by using the uncompensated (Marshallian) and compensated (Hicksian) input demand functions where we assume that firm minimize cost (c) subject to a given level of output (y):

$$c(y, \boldsymbol{w}) = c = \min_{\boldsymbol{x}'}[\textstyle\sum_z \boldsymbol{w}_z x_z] \text{ subject to } y = f(\boldsymbol{x}) \tag{8}$$

where $c(y, \boldsymbol{w})$ is the targeted total cost of producing output y given input x and input prices $\boldsymbol{w}$. In microeconomic theory, the Marshallian demand function ($x_z = g_z(c, \boldsymbol{w})$) that expresses the input demand in terms of the total cost and a vector of input price is actually the true dual of the Hicksian demand function ($x_z = h_z(y, \boldsymbol{w})$) where the firm's input demand is written in terms of output and a vector of input price instead[10]. By substituting the cost function into the

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[10] The Hicksian functions present the amount of input (x_z) demanded at each possible price (w_z) holding output constant. Thus, the Hicksian function only depicts the substitution effects of a change in relative prices.

Marshallian demand function and using the implicit relationship between the Marshallian and the Hicksian functions, the total effect of changes in price is as follows:

$$x_z = h_z(y, \boldsymbol{w}) = g_z(c(y, \boldsymbol{w}), \boldsymbol{w}) \tag{9}$$

By differentiating Eq. (9) with respect to w_z we have: $\frac{\partial x_z}{\partial w_z} = \frac{\partial h_z}{\partial w_z} \equiv \frac{\partial g_z}{\partial w_z} + \frac{\partial g_z}{\partial c} \cdot \frac{\partial c}{\partial w_z}$. Since $c = c(q, \boldsymbol{w})$ and also by Shepard's Lemma, $\frac{\partial c}{\partial w_z} = x_z$, then Eq. (9) is re-arranged and written in terms of substitution and output effects of changes in input price as in Eq. (10):

$$\frac{\partial g_z}{\partial w_z} = \frac{\partial h_z}{\partial w_z} - \frac{\partial g_z}{\partial c} x_z \tag{10}$$

Eq. (8) decomposes the uncompensated price response ($\frac{\partial g_z}{\partial w_z}$) into a substitution effect ($\frac{\partial h_z}{\partial w_z}$) and an output effect ($-\frac{\partial g_z}{\partial c} x_z$). The substitution effect implies, if the price of one input changes, its relative price also changes, which results in a fall in demand for that input whose price increases and an increase in demand for inputs that are substitutable for it. The output effect captures the change in real output as a result of a change in input price. In our empirical analysis, we write the compensated cross-price elasticity between inputs E and K by converting Eq. (10) to Mundlak (1968) elasticity form as follows:

$$\eta_{EK} = \eta_{EK}^{c} - S_K \eta_E \tag{11}$$

where the first term on the RHS of the equation captures the substitution effect and the second term on the RHS captures the output effect, which consists of two components. S_K is the cost share of input K to total expenditure and η_E is the expenditure elasticity of input demand. For own-price elasticity, which is more relevant to this paper, Eq. (11) is written as:

$$\eta_{EE} = \eta_{EE}^{c} - S_E \eta_E \tag{12}$$

The substitution effect is non-positive ($\eta_{EE}^{c} \leq 0$), but the output effect can be negative or positive. If the output effect is positive ($-S_E \eta_E > 0$), this implies that the input is an inferior good; while a negative output effect ($-S_E\eta_E < 0$) suggests that the input is a normal good. The formal case suggests that an increase in the price of energy will have a positive impact on the output level of the producer. The latter suggests that the output level of the producer reduces as energy price increases. The substitution and output effects can be generated from the estimated translog model as follows. The substitution effect, η_{EE}^{c} can be derived by taking the second-order derivatives of the estimated cost function with respect to energy price, that is: $\eta_{EE}^{c}=\frac{\partial^2 \ln c}{\partial \ln w_E^2}$. The output effect consists of two components: S_E is the cost share of energy input to total cost; η_E, which is the expenditure elasticity of energy input demand and can be derived from the implicit relationship between the Marshallian and Hicksian functions in Eq. (12). That is $\eta_E=\frac{\partial \ln x_E}{\partial \ln c}=\left(\frac{\partial \ln x_E}{\partial \ln y}\right)\left(\frac{\partial \ln y}{\partial \ln c}\right)$.

3 Data

This study is based on a panel of 34 industries across 29 European countries[11] over the period 1995–2007[12]. Besides temperature and purchasing power parity exchange rates that were taken from Climate research unit and Tyndall, and Penn World Table (PWT 7.1) respectively, all other series were taken from the World Input-Output Database (WIOD) (Timmer et al., 2015). Table 1 presents variables used in our estimation. Energy input expenditure is calculated as the addition of the value of expenditure on energy inputs (coke, refined petroleum, nuclear fuel, electricity and gas supply) purchased domestically and internationally. Material input expenditure is calculated as the expenditure on intermediate inputs at current purchase. Temperature is measured as the average annual temperature for each country, while the measure of output (y) is gross industrial output that is expressed in

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[11] The industries are listed in the appendix and the 29 European countries consist of Austria, Belgium, Bulgaria, Cyprus, Czec Rep, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherland, Poland, Portugal, Romania, Russia, Slovak Rep, Slovania, Spain, Sweden, Turkey and United Kingdom. Note, we are limited to 29 countries as these are the only European countries, we could sample from our data source (WIOD).

[12] We are constrained to this period, as some of the series (capital compensation, energy use and fixed capital stock) used in our estimation are not available before 1995 and beyond 2007.

millions of national currencies at current prices and employees are in thousand. Energy input expenditure; material input expenditure, capital compensation and labour compensation are in millions of national currencies at current prices while numbers of persons engaged are in thousand. We deflated gross output using the price index of gross output (1995=100). Then used the exchange rates to convert the series to US$. Similarly, we convert the producers' input expenditures to constant (1995=100) prices in each country by applying the implicit price deflator for that industry in each country. We then convert the constant series to US$ using the purchasing power parity exchange rates.

The input prices are therefore computed as follows. The real price of energy (pe) is computed as the ratio of intermediate energy input expenditure at constant prices to energy use in TJ. The real price of capital (pk) is calculated as the ratio of capital compensation to real fixed capital stock; the real price of labour (pl) is computed as the ratio of labour compensation to number of persons engaged and the real price of material (pm) is derived as the ratio of value of intermediate material input expenditure to intermediate material volume.

Table 1: Variable descriptions and summary statistics

Variable	Obs.	Mean	Std. Dev.
CO2 emissions in Gg (kt)	12662	5144.84	29901.7
Energy in TJ	12662	148958.6	743730.6
Real output in millions of US$	12662	195836	170977
Real price of capital in US$	12662	9.38	6.09
Real price of labour in US$	12662	3.97	2.88
Real price of energy in US$/per TJ	12662	17.39	10.97
Real price of material in US$	12662	8.92	8.06
Capital expenditure/cost	12662	0.22	0.13
Labour expenditure/cost	12662	0.19	0.11
Energy expenditure/cost	12662	0.01	0.00
Employee	12662	0.59	0.15
Temperature	12662	10.05	4.58

4 Empirical Results

4.1 Estimated Elasticities of Substitution

Given the insignificant intuitive sense of the parameter estimates of the translog cost function and for the interest of space, we therefore demoted the estimates of the cost function to the appendix. We estimated the specified translog model with both iSUR and multilevel modelling techniques for the entire industries and for sector types with all estimated variables are in their natural logarithm. In addition to mean-adjust of the industry-level variables, we control for heterogeneity across the industries and countries by incorporating additional industrial and countries characteristics (π_t and z_t) respectively in Eq. (3). The mean-adjusted of the industry level variables allows interpreting the ES as elasticities at the sample mean. Although, the results reported in the appendix show that majority of the estimated parameters are statistically significant with expected signs, but we observe that the multilevel modelling performs better in terms of the numbers of significant estimates across the board[13]. The results of the estimated cost function lead to the discussion of the elasticities of substitution discussed above. However, it is necessary to discuss the curvature properties of the estimated cost function before analysing the ES as it provides information about the performance of the fitted cost function.

In principle, a well-behaved cost function must possess an economic property that satisfies the condition of monotonicity at both sample mean and outside the sample mean. Given the positive and statistically significant of the coefficients of the output and input prices at the industry level as reported in Tables A1 and A2[14], our results suggest that the estimated cost functions strongly satisfied the condition of monotonicity at the sample mean. Further, we also test these curvature properties of the fitted cost function by verifying if the

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[13] Specifically, most of the estimates at country-level and their interactions with industry-level are significant. This reinforces the argument stated above that industries are not operating in isolation as their activities are closely integrated with aggregate activities, thus, there is a need to control for aggregate effects.

[14] These Tables are available on request.

condition of monotonicity is also satisfied outside the sample mean. Our analysis shows that monotonicity is strongly satisfied outside the sample mean with at least on average 76% of the data points are monotonic[15]. The monotonic condition suggests that our estimated cost functions are non-decreasing in both output and input prices.

Following the estimation of the translog cost function, we verified the possibility of factor substitution by computing the AES, CPE and MES using Eqs. (5 – 7). We used the estimated parameters of the iSUR and the multilevel model reported in Table A1 and A2 in computing the substitution elasticities[16]. Empirical elasticities at the sample mean are presented in Table 2 and 3. Majority of the estimates of the AES reported in Table 2 are positive and statistically significant. The positive estimates of our elasticities indicate that energy and non-energy inputs are substitutes in most cases, though; we find capital and energy as complements for the manufacturing with multilevel modelling. Our estimates indicate a relatively strong ES between energy and non-energy inputs as most of the elasticities reported in Table 2 are close or greater than one. However, our results display a weak/moderate ES between capital and energy for the primary and service sectors.

As theoretically expected, the estimates of the MES are positive across board and statistically significant. The MES reinforces that energy and non-energy inputs are substitutes across sectors. Furthermore, the estimates of the AES and the MES show that the substitution between energy and labour is relatively stronger compared to others ES, while capital and labour are the least substitutes. Specifically, to the MES the elasticity of substitution η_{EL} = 1.74 suggests that a 1% increase in the price of labour is associated with about 1.7% increase in energy-labour input ratio. The estimates of our ES are in line with existing literature. For

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[15] As the entire sample comprises data points for the primary, manufacturing and service sectors, we verified the monotonic condition outside the sample mean with the entire sample only and the results are available on request.

[16] However, substantial part our explanation is limited to the elasticities of substitution derived from the estimates of the multilevel modelling as this is our model of interest.

the AES, our estimates are closer to Adetutu et al. (2016) and for the MES; our estimates are similar to Haller and Hyland (2014).

For comparison purposes, the elasticities reported in Table 2 indicate that the values of the AES are bigger than that of the MES. The results suggest that the AES demonstrate a stronger technical substitution between factor inputs than the MES. One reason that might account for the difference between the values of the AES and MES could be as a result of the restrictive symmetric relationship exhibits in input combinations under the AES, as it explains the potential input adjustment relative to factor share, if the price of other input changes. While, in contrast, MES exhibits a flexible asymmetric relationship in input combinations, as it captures the change in the ratio of two inputs when the price of one of the inputs changes. Ideally in practice, the producers are more concerned with the relative change rather than actual change in input demand when the price of one input changes. Therefore, the restrictive assumption of actual change in input demand under the AES rather than the relative change in input as other input price rises might be a possible explanation for the overstate of the AES.

The own and cross-price elasticities for different sectors are reported in Table 3. We find majority of the elasticities reported in Table 3 statistically significant across the board. As expected, all own-price elasticities are negative and significant. With few exceptions, the estimates of the CPE generally indicate that factor inputs are substitutes given their positive coefficients. However, we observe a relative weak substitutability among factors in CPE compared to the AES and MES as majority of the CPE less than 0.5. This suggests that the substitution possibility among factors is predominantly weak, with the substitution of capital for energy (η_{KE}) demonstrates the weakest, while the substitution of energy for labour (η_{EL}) demonstrates the strongest in general. Moreover, the elasticities reported in Table 3 demonstrate considerable variations in terms of asymmetric from factor to factor. For instance, although, the demand for labour demonstrates a weak response to changes in energy prices

(η_{LE} = 0.13), but the demand for energy displays a strong response to changes in labour prices (η_{EL} = 1.05). Further, in most cases, our results show considerable differences in the estimates of the CPE derived from the iSUR and the multilevel technique. For instance, the elasticities from the iSUR (multilevel) indicate substitutability (complementarity) between capital and energy for the manufacturing sector. On the other hand, although, not statistically significant, but the elasticities from the iSUR indicates complementarity while that of the multilevel technique indicates substitutability between capital and energy for the service sector.

Across the board, our estimated elasticities indicate that energy is the most price responsive input, with average estimated own-price elasticities of about -0.94 and -1.07 from the iSUR and multilevel techniques respectively. In contrast, we find labour as the least price responsive input with average estimated elasticities of about -0.65 and -0.68 from the iSUR and multilevel techniques respectively. These results are consistent with Haller and Hyland (2014) as they find energy as the most price responsive input with an estimated elasticity -1.46%, and labour as the least price responsive input with an estimated elasticity -0.48%. Also, Griffin and Gregory (1976); Nguyen and Streitwieser, (1999) find energy as the most price-elastic input with Griffin and Gregory (1976) find labour as the least price-elastic input with an average estimated elasticity -0.23, which is similar to Arnberg and Bjørner (2007).

Table 2
Elasticity of substitution estimates.

	Elasticities with iSUR estimates				Elasticities with multilevel model estimates			
	Whole	Primary	Manufacturing	Service	Whole	Primary	Manufacturing	Service
Allen-Uzawa elasticities								
$\sigma_{KL} = \sigma_{LK}$	0.95***	1.25***	–0.43***	1.26***	0.35***	0.87***	0.72***	0.76***
	(0.02)	(0.03)	(0.03)	(0.02)	(0.04)	(0.08)	(0.09)	(0.04)
$\sigma_{KE} = \sigma_{EK}$	0.82***	0.43***	2.57***	0.66**	1.43***	0.24	–0.43***	–0.07
	(0.07)	(0.10)	(0.19)	(0.09)	(0.17)	(0.27)	(0.03)	(0.35)
$\sigma_{LE} = \sigma_{EL}$	2.33***	1.12***	3.45***	1.31***	3.53***	2.61***	2.23***	3.31***
	(0.05)	(0.07)	(0.14)	(0.07)	(0.16)	(0.19)	(0.66)	(0.31)
Morishima elasticities								
σ_{KL}	0.94***	1.05***	0.92***	1.07***	0.79***	1.04***	0.58***	0.95***
	(0.01)	(0.01)	(0.03)	(0.02)	(0.03)	(0.05)	(0.08)	(0.03)
σ_{KE}	1.10***	0.80***	0.99**	0.91***	1.24***	0.96***	1.22***	1.03***
	(0.01)	(0.02)	(0.03)	(0.02)	(0.02)	(0.06)	(0.06)	(0.19)
σ_{LE}	1.16***	0.84***	1.12***	0.93***	1.32***	1.06***	1.26**	1.15***
	(0.01)	(0.02)	(0.04)	(0.02)	(0.10)	(0.11)	(0.32)	(0.19)
σ_{LK}	0.84***	0.94***	0.75***	0.95***	0.75***	0.79***	0.58***	0.85***
	(0.01)	(0.01)	(0.03)	(0.03)	(0.04)	(0.04)	(0.14)	(0.03)
σ_{EK}	0.82***	0.77***	0.58***	0.83***	0.94***	0.66***	0.97***	0.70***
	(0.02)	(0.01)	(0.04)	(0.01)	(0.04)	(0.06)	(0.14)	(0.09)
σ_{EL}	1.35***	1.00***	1.31***	1.09***	1.74***	1.67***	1.58***	2.01***
	(0.02)	(0.02)	(0.07)	(0.03)	(0.10)	(0.07)	(0.28)	(0.13)

***, ** and * represent statistically significant at 1%, 5% and 10% level of significance. Standard errors are in parentheses.

Table 3
Own-and cross-price elasticities.

	Elasticities with iSUR estimates				Elasticities with multilevel model estimates			
	Whole	Primary	Manufacturing	Service	Whole	Primary	Manufacturing	Service
η_{KK}	–0.68***	–0.68***	–0.65***	–0.72***	–0.69***	–0.61***	–0.63***	–0.71***
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)	(0.02)
η_{LL}	–0.65***	–0.59***	–0.73***	–0.62***	–0.67***	–0.72***	–0.67***	–0.68***
	(0.01)	(0.01)	(0.16)	(0.01)	(0.02)	(0.03)	(0.05)	(0.02)
η_{EE}	–1.07***	–0.79***	–1.01***	–0.89***	–1.19***	–0.95***	–1.10***	–1.03***
	(0.01)	(0.02)	(0.04)	(0.02)	(0.09)	(0.11)	(0.29)	(0.18)
η_{KL}	0.29***	0.45**	0.19**	0.45***	0.10***	0.31***	–0.11***	0.27***
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.03)	(0.02)
η_{KE}	0.03***	0.02***	–0.03***	0.02**	0.05***	0.01***	0.11***	–0.00
	(0.00)	(0.00)	(0.06)	(0.00)	(0.01)	(0.12)	(0.02)	(0.01)
η_{LE}	0.09***	0.05***	0.10***	0.04***	0.13***	0.11***	0.15***	0.11***
	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.03)	(0.02)
η_{LK}	0.16***	0.26***	0.09**	0.24***	0.06***	0.18***	–0.05***	0.14***
	(0.00)	(0.00)	(0.04)	(0.00)	(0.01)	(0.01)	(0.02)	(0.00)
η_{EK}	0.14***	0.09***	–0.08***	0.12**	0.25***	0.05***	0.33***	–0.01
	(0.01)	(0.01)	(0.01)	(0.02)	(0.03)	(0.04)	(0.11)	(0.02)
η_{EL}	0.69***	0.41***	0.58***	0.47***	1.05***	0.95***	0.89***	1.32***
	(0.02)	(0.01)	(0.24)	(0.02)	(0.05)	(0.05)	(0.29)	(0.02)

***, ** and * represent statistically significant at 1%, 5% and 10% level of significance. Standard errors are in parentheses.

4.2 Estimated Decomposition Results

To this point, we mainly focused on the pure substitution possibilities among factors if there is an absolute or relative change in input price without accounting for the output effect of the change in price. To recap, we argue that since the pure ES estimated assume constant level of output in the face of changes in input price, then, ES is not a complete representation of input adjustment. Consequently, the ES undermines the true nature of firm's behaviour, as firms are likely to adjust output accordingly not even only to changes in factor price, but also to technological change, shocks and market imperfections. Hence, we measure the output effect as it provides the missing point in input adjustments as factor price changes.

In our analysis, we explore the output effect of a change in energy price following the estimation of Eqs. (3 and 4) by decomposing derived energy demand into substitution and output effects with Slutsky equation discussed in section 2. Our focus in this paper is own-price effect as expressed in Eq. (12) rather than cross-price effect. To analyse the decomposition effects, we used the parameter estimates of the iSUR and multilevel models reported in Table A1 and A2 to derive separate substitution and output effects for each of the techniques. The estimates of the substitution and output effects for whole sector and sector types are reported in Table 4[17]. The estimates of the substitution effects from the multilevel model are negative and statistically significant as expected. The results, which are in conformity with economic theory suggest that producer tend to reduce energy use as price increases and thus sort out for alternative factor inputs with relative cheap prices.

In contrast, we find a mix results for the iSUR technique, which is questionable as substitution effect takes negative (whole and manufacturing) and positive (primary and

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[17] The estimation of the output effect is not straightforward unlike the substitution effect, which is directly obtainable from the estimated translog model, therefore, generating the standard error is problematic. Moreover, since the output effect can either be positive or negative, the standard error is considered inconsequential here. Again, the estimates reported in Table 4 are sample means of substitution and output effects.

service) values and statistically significant. This result contradicts the theory as positive substitution effect indicates that producer increases the amount of energy use as energy price increases.

In general, we observe that the substitution effect from the multilevel modelling is bigger than that of the iSUR in absolute terms, but smaller than the estimates reported in Adetutu et al. (2016). One possible explanation why our results differ from that of Adetutu et al. (2016) could be the choice of analysis and sampled countries as they decomposed energy demand for individual BRIIC countries, while this paper decomposed energy demand for a panel of industries across European countries. Arguably, industries in fast emerging economies such as BRIIC are likely to be more sensitive to changes in energy price as they exhibit a very strong substitution between energy and other inputs as demonstrated by Adetutu et al. (2016).

Table 4
Decomposition effects of derived energy demand with respect to changes in energy price

	Based on iSUR estimates		Based on multilevel estimates	
	Substitution effect	Output effect	Substitution effect	Output effect
Whole	–0.00406* (0.000)	0.00013	–0.00830* (0.001)	–0.00044
Primary	0.00737* (0.001)	–0.00074	0.00032 (0.005)	–0.00055
Manufacturing	–0.00269* (0.000)	0.00007	–0.00654* (0.001)	–0.00038
Service	0.00232* (0.001)	–0.00028	–0.00192* (0.001)	0.00022

* represent statistically significant at 5% level of significance with standard errors in parentheses. The estimates reported here are the sample means.

For the output effect (the relevance lies in the sign not the magnitude), the results based on the estimates of iSUR and the multilevel model differs by sign for the whole, manufacturing and service sectors. A positive output effect implies that energy input is an inferior factor, which suggests that a firm is insensitive to a rise in energy price and therefore fails to reduce output accordingly. In contrast, a negative output effect indicates that energy is a normal factor input, therefore a rise in energy price is expected to increase the firm's production cost and consequently reduce the firm's output level. Intuitively, the latter case represents the true behaviour of a rational cost-minimizing firm, as we expect producer to reduce output in order to minimize loss when cost of production increases. Further, it is more logical to consider energy as a normal good given its historical essentiality in the production process.

Again, we consider the multilevel modelling as a preferred method given the estimated negative output effects. The positive output effect for the service sector is justifiable given the nature of the service sector as they mainly provide services. This is because employers are unlikely to reduce the quality of their services or reduce the level of services by retrench workers, just for the sake of increase in energy price unlike in the manufacturing and primary sectors where energy input forms the major part of their production process. As expected, the estimates of the output effects are smaller than that of the substitution effects in absolute terms indicating that the substitution effect dominates the output effect. The results indicate that the total effects arising from increased in energy price is consistent with economic theory, as a rise in energy price will reduce the producer’s energy demand.

However, notwithstanding the intuition behind the estimates of the output effect, the estimates are generally not different from zero, which is similar to Adetutu et al. (2016). With this outcome, it is logical to conclude that the output effect is less likely to have a significant implication on carbon reduction via reduction in energy use. Given this argument and in addition to the fact that the multilevel model is our preferred method of analysis as discussed above, we only analysed the relationship between carbon emissions and the decomposition effects derived from the multilevel model in section 4.3. Therefore, it is in the context of these results we extend the literature by carrying out an exploratory investigation to analyse the relevance of the output and substitution effects (arising from increase in energy price) on carbon emissions.

4.3 Energy Demand Decomposition and CO_2 Emissions

Following the decomposition of derived energy demand into substitution and output effects, we now focus on the implications of these effects on CO_2 emissions. Since we have a three-level hierarchical dataset and to control for heterogeneity at each level of the data we employ a three-level multilevel modelling approach where country is level 3 and industry is level 2 number of observation is level 1. Our three-level multilevel model is specified as follows:

$$co_{ijt} = X'_{ijt}\delta + CR'_{jt}\gamma + u_j^{(3)} + u_{ij}^{(2)} + \epsilon_{ijt} \tag{13}$$

where *i, j* and *t* denote industries, countries and time period respectively. The dependent variable co_{ijt} denotes the CO_2 emissions for industry *i* in country *j* in time period *t*. *X* denotes a vector of industry-level variables including estimated substitution and output effects. To analyse the substitution and output effects in Eq. (13), we estimated the substitution and output effects outside of the sample mean, that is for every data point. *CR* represents a vector of country-level variables. The error terms assumed to be independently and identically distributed (*IID),* with zero mean and their respective variances:

$$u_j^{(3)} \sim N(0, \sigma_v^2); \qquad u_{i,j}^{(2)} \sim N(0, \sigma_u^2); \qquad \in_{i,j,t} \sim N(0, \sigma_\in^2)$$

where $u_j^{(3)}$ is the error term for the *j*th country, $u_{i,j}^{(2)}$ represents the nested effect of *i*th industry within the *j*th country, and $\epsilon_{i,j,t}$ is the remaining error term for *t*th response time of *i*th industry within the *j*th country.

We estimated Eq. (13) without and with the decomposition effects. The estimated results are reported in Tables 5 and 6 respectively. For analysis purposes, all estimated variables are in their natural logarithm and we centred the industry level variables on the log of their group means so that their estimated parameters can be interpreted as elasticities within country. The country level variables are the group means of the industry level variables and their coefficients would be interpret in form of between-country effect or contextual effect of a given variable[18]. As output is one of the variables estimated, we acknowledge that a strand in the literature (Halicioglu, 2009; Ghosh, 2010; Pao and Tsai, 2011) argues that output could mirror carbon emissions; as a result, Eq. (13) might suffer from endogeneity problem. However, another strand in the literature (Ang, 2007; Soyta and Sari, 2007; Zhang and Cheng, 2009; Chang, 2010) of emission-output nexus refutes this claim by arguing that there is a unidirectional causality running from output to carbon emissions. This implies there is no consensus in the existing literature regarding the direction of causality between output and emissions. We leverage on this inconclusive evidence in the literature of output-emissions nexus and estimated Eq. (13) on the assumption that only output drives emissions, but not the other way around in our case.

Notwithstanding the strand in the literature we support, we otherwise test for possible endogeneity in Eq. (13). Similarly, given that our analysis is based on European countries, therefore there is tendency that our sampled countries may respond to common shocks as their economic activities, energy policies/consumption and environmental policies may be correlated. Hence, we test for potential cross-sectional dependency in our panel data model. Further, we acknowledge that cross-country analysis may be prone to unobserved heterogeneity, however, since our method of analysis (multilevel model) is designed to account for clustered unobserved heterogeneity, we do not test for unobserved heterogeneity in Eq. (13). This is unlike Tajudeen et al. (2018) that do not account for unobserved heterogeneity and therefore, also test for unobserved heterogeneity in additional to endogeneity and cross-section dependency tests (this should be in response to reviewer's).

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[18] Hox et al. (2010) and Steele (2008) provide explanation on using the means of lower level variables as higher level variables in multilevel model.

We used the popular Durbin-Wu-Hausman approach to test for endogeneity of output using its first lag as instrument in Eq. (13). Since we estimated Eq. (13) for different sectors, we therefore performed the test for the whole and sector types. For all the sectors, the test failed to reject the null hypothesis of exogeneity for output at 5% level of significance with χ^2= 0.053 (*pvalue* = 0.94). Similarly, for sector types (primary, manufacturing and service sectors), the test failed to reject the null hypothesis of exogeneity for output at 5% level of significance with χ^2= 3.412 (*pvalue* = 0.06), χ^2= 1.993 (*pvalue* = 0.16) and χ^2= 0.275 (*pvalue* = 0.60) respectively. Further, we test for cross-section dependency by using the approach developed in Pesaran (2006). The Pesaran test reject the null hypothesis of no cross-sectional dependency with *pvalue* = 0.00. As a result, we follow the conventional practice in the literature to account for cross-sectional dependency by reporting the clustered standard errors of the results presented in Tables 5 and 6, which are more robust to more general form of cross-sectional dependency (Driscoll and Kraay, 1998). Our results are similar to Tajudeen et al. (2018).

The results of the estimated model without decomposition are reported in Table 5. The results show that majority of the estimated variables for the whole and service sectors are statistically significant with expected sign. However, this is not the case for the primary and the manufacturing sectors sector as majority of the estimates are not statistically significant. As expected, energy, output and employees all have positive relationship with carbon emissions. Generally, we find energy as the main driver of carbon emissions with relatively large within-country (0.24) and between-country elasticities (0.58). The larger value of the between-country elasticity compared to the within-country elasticity indicates that aggregate energy use has a stronger influence on carbon emissions than industry-level energy use. The negative coefficient of the output squared indicates that at the initial stage of production, industrial carbon emissions increase as output increases, but at a later stage, industrial emissions fall as output increases[19]. This shows that sustainable growth of economic activity is an important factor in reducing CO_2 emissions. The statistical significance of some of the estimated country-level variables demonstrates the importance for controlling for country-level effects while using industry level dataset. The results reinforce the fact that industries are not operating in isolation as their activities evidently tied to macroeconomic activities.

Further, temperature is negatively related to CO_2 emissions with estimated elasticities appeared to be statistically significant across the board except for the manufacturing sector. Although, not statistically significant, but the estimate –0.12 suggests that a 10% increase in temperature is associated with about 1.2% reduction in carbon emissions. One possible explanation for the inverse relationship between carbon emissions and temperature is that industries are likely to reduce their energy consumption in warm weather period and subsequently reduce the amount of carbon emissions emit during this period.

The results of the random part explain the unobserved heterogeneity in our dataset. The results demonstrate the strengths of multilevel modelling in terms of its ability to account for and separate the unobserved heterogeneity at different levels of the data, which iSUR ignores. The coefficients on error terms σ_v^2, σ_u^2 and σ_ε^2 represent unobserved variations in country, industry and time period respectively with most of the estimated coefficient being significant. To measure the extent of contextual unobserved heterogeneity in carbon emission, we employ the intra-class correlation coefficient (ICC). The coefficient of the ICC 0.09 suggests that just 9% of the unexplained variations in industrial carbon emission are traceable to country differences. In other words, 91% of unobserved heterogeneity in industrial carbon emissions is due to industry differences.

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[19] The result support the environmental Kuznet curve hypothesis, which indicates that environmental pressure increases up to a certain level as income rises then decreases as income rises above certain level (Dinda, 2004; Jalil and Mahmud, 2009).

Table 5
Estimated results for CO_2 emissions without decomposition effects (standard errors in parentheses)

Fixed part:	Whole	Primary	Manufacturing	Service
Constant	–1.80	–3.93**	–2.62*	–1.04
	(1.63)	(1.66)	(1.41)	(2.57)
Industry-level variables				
Energy	0.24***	0.25**	0.29***	0.19***
	(0.05)	(0.13)	(0.07)	(0.05)
Output	0.11	0.16	0.06	0.21***
	(0.08)	(0.29)	(0.08)	(0.09)
Output squared	–0.01*	0.01	–0.01	−0.02***
	(0.01)	(0.02)	(0.01)	(0.01)
Employee	0.11**	−0.06	0.01	0.17**
	(0.05)	(0.08)	(0.05)	(0.07)
Country-level variables				
Temperature	–0.12	0.00	–0.28***	0.07
	(0.12)	(0.11)	(0.11)	(0.17)
Energy	0.58***	0.90***	0.89***	0.21
	(0.20)	(0.28)	(0.19)	(0.32)
Output	0.08	−0.06	0.08	0.15
	(0.09)	(0.25)	(0.11)	(0.09)
Employee	0.48**	0.23	–0.00	1.03***
	(0.19)	(0.33)	(0.19)	(0.37)
Random part:				
σ_v^2	0.23**	0.22	0.27**	0.86***
	(0.09)	(0.19)	(0.12)	(0.26)
σ_u^2	2.36***	0.75**	2.32***	1.64***
	(0.23)	(0.19)	(0.16)	(0.12)
σ_ε^2	0.07***	0.04***	0.06***	0.08***
	(0.02)	(0.01)	(0.00)	(0.00)
Intra-class correlation	0.09**	0.21	0.10**	0.33
	(0.03)	(0.18)	(0.04)	(0.08)

***, ** and * represent statistically significant at 1%, 5% and 10% level of significance. Intra-class correlation coefficient $(ICC) = \frac{\sigma_v^2}{\sigma_v^2+\sigma_u^2+\sigma_\varepsilon^2}$.

To reiterate, we only present the results of the decomposition effects derived from the estimated multilevel model as our preferred model in Table 6. We find our control variables reliable as a majority is statistically significant and demonstrate minimum or no variation compared to the estimates from the model without decomposition. Considering only statistically significant estimates, as expected, the substitution effect has a negative relationship with carbon emission with estimated elasticities –0.64 and –0.54 for the whole and service sectors respectively. The estimated elasticity –0.64 indicates that a 10% increase in substitution effect arising from increase in energy price is associated with approximately 6.4% reduction in industrial CO_2 emissions. This result suggests that a rational producer will reduce energy use when energy price increases by consuming less energy, which could be in form of using more alternative sources of fuel, other substitutable inputs, more energy efficient or even the combination of the measures listed. The statistically significant and reasonable values of the substitution effects depict the degree of sensitivity of the producers to changes in price via the use of other inputs. However, the substitution effect for the primary sector is positive, though not statistically significant. The result would have contradicted theoretical exposition if it was significant, as it would imply that producers use more energy as energy price increases.

Similarly, the estimates of the output effect are negative across board and just like the substitution effect, only the estimates for the whole and service sectors are statistically significant. The negative output effect implies that energy is a normal good, which is logical given its historical importance in the production setting. The implication of the negative output effect is that producer is likely to adjust output accordingly following an increase in energy price and this could result in higher production cost if substitution is hard. The results suggest that output adjustment following an increase in production cost is associated with a reduction in CO_2 emissions. However, the values are generally smaller compared to the estimates of the substitution effect. For instance, the output effect –0.06 suggest that a 1% increase in output effect as a result of increase in price is associated with about 0.06% reduction in carbon emissions. In general, the impact of the output effect is relatively small compared to the impact of the substitution effect and that makes the substitution effect to be the dominant factor. The implication of these results is that the output effect may not be as worthy to be considered as previous literature suggested when analysing the decomposition effect of an input. In overall, the impact of the decomposition effect arising from the increase in energy price is associated with reduction in carbon emissions given the negative combination of the substitution and output effects.

Table 6

Estimated results for CO_2 emissions with the decomposition effects (standard errors in parentheses)

Variable	Whole	Primary	Manufacturing	Service
Constant	–2.11	–2.79	–2.28	–1.72
	(1.66)	(1.77)	(1.52)	(2.66.)
Industry-level variables:				
Substitution effect	–0.64***	0.28	–0.59	–0.54**
	(0.23)	(1.14)	(0.43)	(0.23)
Output effect	–0.06*	–0.86	–0.00	–0.09***
	(0.03)	(1.45)	(0.02)	(0.03)
Output	0.27***	0.08	0.28**	0.29***
	(0.02)	(0.23)	(0.08)	(0.04)
Output squared	–0.02***	0.02	–0.01*	–0.02***
	(0.01)	(0.02)	(0.01)	(0.00)
Employee	0.17**	–0.06	0.08	0.20***
	(0.05)	(0.08)	(0.06)	(0.02)
Country-level variables:				
Temperature	–0.12	–0.10	–0.33***	0.09
	(0.28)	(0.12)	(0.11)	(0.17)
Energy	0.48**	0.77***	0.74***	0.16
	(0.21)	(0.33)	(0.20)	(0.33)
Output	0.17*	–0.20	0.20*	0.19*
	(0.09)	(0.24)	(0.11)	(0.10)
Employee	0.64***	0.40	0.16	1.18**
	(0.20)	(0.36)	(0.21)	(0.38)
Random part:				
σ_v^2	0.17**	0.25	0.25	0.80**
	(0.07)	(0.22)	(0.16)	(0.32)
σ_u^2	3.10***	0.91***	3.39***	1.91***
	(0.24)	(0.20)	(0.20)	(0.21)
σ_ε^2	0.07***	0.04***	0.07***	0.08***
	(0.02)	(0.01)	(0.01)	(0.02)
Intra-class correlation	0.05***	0.21	0.07**	0.29**
	(0.02)	(0.18)	(0.03)	(0.07)

***, ** and * represent statistically significant at 1%, 5% and 10% level of significance. Intra-class correlation coefficient $(ICC) = \frac{\sigma_v^2}{\sigma_v^2+\sigma_u^2+\sigma_\varepsilon^2}$. Note: the variable 'output' measured industrial economic activity which is different from the 'output effect' which measured output adjustment of a change in energy price.

The results of the random part in Table 6 show a decrease in the intra-class coefficients if allowing for decomposition effect as compared to those reported in Table 5. The coefficient of the ICC 0.05 suggests that just 5% of the unexplained variations in industrial carbon emission are traceable to variations in country while allowing for decomposition effect. The insignificant of the primary sector's ICC (21%) indicates that country effect plays no role in the unexplained variations of the primary sector's CO_2 emissions.

5 Concluding Remarks and Further Work

This paper develops a two-step procedure to analyse the decomposition effect of derived energy demand on CO_2 emissions. Our empirical analysis makes nontrivial contributions to the literature of inter-factor substitution and decomposition effects by comparing the estimates of the iSUR and the multilevel modelling techniques and then support in favour of the latter approach. To do so, we use hierarchical industry dataset across 29 European countries for the period 1995–2007. To analyse inter-factor substitution, we estimate a translog cost function with the popular iSUR and multilevel modelling. Unlike the iSUR, the multilevel model accounts for the cluster-level heterogeneity in our dataset and we further argue that failure to account for this heterogeneity may lead to unreliable estimates. Thereafter, we use the estimates of the estimated translog function from both techniques to decompose changes in energy demand resulting from changes in price into substitution and output effects. We conclude our analysis by investigating the impact of the substitution and output effects on CO_2 emissions having controlled for other competing forces.

The main results emerged from our analysis are as follows.

- Given the strengths and preference of the multilevel modelling approach over the iSUR in our empirical analysis, this study argues for the importance of using a more suitable modelling technique when analysing the decomposition effects of changes in production factor as failure to do so could lead to unreliable estimates.

- In general, the results of the AES and MES indicate strong substitutability between energy and other inputs. However, the estimates of the cross-price elasticity indicate weak substitutability between energy and other inputs.

- The estimated decomposition results show that changes in derived energy demand are largely dominated by substitution effect in absolute terms.

- Although we find both the substitution and the output effects arising from increase in energy price to be inversely related to the carbon emissions, but the impact of the substitution effect is stronger.

In summary, our results suggest that the output effect arising from increase in energy price may not play a significant role in reducing CO_2 emissions. Our results can be evidenced in practice, as one would expect a cost minimising firm to adjust both output and inputs accordingly when inputs' prices increased. Our findings are in conformity with the theory as increase in inputs' prices is expected to increase production cost and subsequently reduces production. Given the positive relationship between emissions and economic activity, therefore, one would expect carbon emissions to reduce as firms adjust output accordingly as a result of increase in production cost.

The policy implications that can be drawn from our analysis are as follows. Firstly, the capital-energy substitution suggests that policy to incentivise production sectors for being capital efficient should be promoted, as consequently, such policy tends to reduce carbon emissions much more as more capital equipment (less carbon intensive) are used in production. Secondly, the insignificant of the output effect suggests that producers do not necessarily need to reduce the level of output as they can substitute other inputs for energy without any loss in production if energy price increases. Therefore, any energy policy targeted to increase energy/carbon taxes is less likely to be counterproductive. The result is similar to the finding by Presley et al. (2018) as they suggest that the switch from the use of a more polluting fuel type to a less polluting fuel type as a result of an implementation of energy conservative policy will have no adverse effect on economic growth.

We hope our findings serve as a blueprint for European policy makers and other developed countries that policies targeted to increase energy/carbon taxes are not likely to retard business activities. Thirdly, we argue that there is a need to observe the implications of factor substitution in different sectors of the economy and that of economy at large before formulating aggregate or sector specific energy related policy. This is important as any policy being formulated to reduce carbon emission without considering the substitution potential in production sectors is likely to be ineffective if substitution between inputs is hard. More importantly, we find that the overall effect of an increase in energy price will reduce carbon emissions but should be supported by sustainable growth and cleaner factor substitution. These findings reinforce Tajudeen et al. (2018) that the use of cleaner energy substitution are important factors in reducing CO2 emissions.

The main limitation of this study is lack of data availability as we would have explored beyond the scope of the study, which is limited to 13 years (1995-2007) and 29 sampled countries. We are limited to 29 countries as these are the only European countries, we could sample from our data source. Similarly, we are constrained to 13 years as some of the series (as mentioned in the data section) used in analysis are not available before 1995 and beyond 2007.

For further work, we hope future research can focus on the decomposition analysis for different types of fuel. As such, research would not only provide insightful information about the substitution and output effects of different fuel types, but also suggest the fuel type that is more environmentally.

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Appendix

List of ISIC Rev.4 (NACE Rev.2) Sectors

S/N	**NACE Description**	**Sector**
1	secAtB	Agriculture, Hunting, Forestry and Fishing
2	secC	Mining and Quarrying
3	sec15t16	Food, Beverages and Tobacco
4	sec17t18	Textiles and Textile Products
5	sec19	Leather, Leather and Footwear
6	sec20	Wood and Products of Wood and Cork
7	sec21t22	Pulp, Paper, Paper , Printing and Publishing
8	sec23	Coke, Refined Petroleum and Nuclear Fuel
9	sec24	Chemicals and Chemical Products
10	sec25	Rubber and Plastics
11	sec26	Other Non-Metallic Mineral
12	sec27t28	Basic Metals and Fabricated Metal
13	sec29	Machinery, Nec
14	sec30t33	Electrical and Optical Equipment
15	sec34t35	Transport Equipment
16	sec36t37	Manufacturing, Nec; Recycling
17	secE	Electricity, Gas and Water Supply
18	secF	Construction
19	sec50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
20	sec51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
21	sec52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
22	secH	Hotels and Restaurants
23	sec60	Inland Transport
24	sec61	Water Transport
25	sec62	Air Transport
26	sec62	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
27	sec64	Post and Telecommunications
28	secJ	Financial Intermediation
29	sec70	Real Estate Activities
30	sec71t74	Renting of M&Eq and Other Business Activities
31	secL	Public Admin and Defence; Compulsory Social Security
32	secM	Education
33	secN	Health and Social Work
34	secO	Other Community, Social and Personal Services

Notes: based on the NACE classification, the industries could be classified into: primary sector which consists of S/N 1 to 2, manufacturing sector consists of S/N 3 to 18 and service sector consists of S/N 19 to 34.

Appendix A1: Estimated translog cost function with multilevel modelling

	Whole	Primary	Manufacturing	Service
Fixed part:				
Intercept	–0.20***	0.28**	–0.25	–0.01
ly1_y	0.65***	0.63***	0.66***	0.63***
ly11_y^2	–0.02***	0.00	–0.01***	–0.02***
ly1t_yt	0.01***	0.01**	0.01***	0.00
ly1w1_yk	–0.00	0.06***	–0.00	0.00
ly1w2_yl	–0.06**	–0.01	0.02***	–0.03***
ly1w3_ye	–0.01	–0.01	–0.01**	0.00
w1_k	0.14***	0.23***	0.16***	0.11***
w2_l	0.27***	0.30***	0.30***	0.29***
w3_e	0.05***	0.01***	0.04***	0.03***
w11_k^2	0.02***	0.04***	0.03***	0.02***
w22_l^2	0.00	–0.03***	0.01***	–0.02***
w33_e^2	–0.01***	0.00	–0.01***	0.00
w12_kl	–0.03***	–0.01	–0.05***	–0.02***
w13_ke	0.00**	–0.01	0.01***	–0.01***
w23_le	0.03***	–0.03**	0.03***	0.03***
w1t_kt	0.00***	0.01***	0.01***	0.00***
w2t_lt	–0.00***	0.00	0.00	–0.01***
w3t_et	0.00***	0.01***	0.00	0.00***
t	0.02***	0.02***	0.02***	0.03***
tsq_t^2	0.00***	0.00***	0.00	0.00
Country-level variables				
Y	–0.21***	–0.27***	–0.22***	–0.14***
W1-K	–0.11***	–0.07***	–0.14***	–0.06***
W2-L	–0.12***	–0.09***	–0.16***	–0.08***
W3-E	0.02***	–0.01	–0.02***	0.01
W4-M	–0.41***	–0.09	–0.36***	–0.51***
Industry-country interactions				
Yt	–0.01***	0.00	–0.01***	–0.01***
Yy	0.06***	–0.01	0.05***	0.06***
Yw1_Yk	0.01***	–0.01	0.02***	0.01
Yw2_Yl	0.01***	0.00	0.01	0.02***
Yw3_Ye	0.01	0.01	–0.01*	–0.03***
W1t-Kt	0.00	0.00	0.00	0.00
W2t-Lt	0.00	0.01***	0.00*	0.00
W3t-Et	–0.01***	–0.01**	–0.01***	–0.01***
W4t-Mt	0.01***	0.00	0.00	0.00
W1y-Ky	0.02***	–0.02	0.02***	0.00
W2y_Ly	–0.02***	–0.02	–0.05***	0.02***
W3y_Ey	0.01***	–0.05***	0.01***	0.01
W4y_My	–0.02***	0.06***	–0.01	–0.03***
W1w1_Kk	–0.04***	–0.05***	–0.05***	–0.03***
W2w1_Lk	0.04***	0.00	0.03***	0.04***
W3w1_Ek	–0.00***	–0.01**	0.00*	0.00***
W4w1_Mk	0.00	0.04***	0.02***	0.00
W1w2_Kl	0.05***	0.13***	0.06***	0.03
W2w2_Ll	0.03***	0.00	0.01	0.08***
W3w2_El	–0.01***	–0.07***	–0.01***	0.00***
W4w2_Ml	–0.05***	–0.05**	–0.05**	–0.08
W1w3_Ke	0.01***	–0.02***	0.00	–0.01
W2w3_Le	–0.05***	–0.02	–0.04***	–0.09***
W3w3_Ee	0.01***	0.03***	0.01***	–0.00**
W4w3_Me	0.03***	0.04**	0.02**	0.07***
σ_v^2	0.53***	0.21**	0.52**	0.56**
σ_u^2	0.14***	0.16***	0.09**	0.12**
σ_ε^2	0.02***	0.01***	0.01**	0.01**
Intra-class correlation	0.77**	0.55**	0.82*	0.80**

Appendix A2: Estimated translog cost function with iSUR

	Whole	Primary	Manufacturing	Service
Cost share equation for capital				
ly1	0.02***	0.03***	–0.00	0.05***
w1	0.02***	0.02***	0.03***	0.02***
w2	–0.00***	0.02***	–0.01***	0.02***
w3	–0.00**	–0.01***	–0.01***	–0.00***
t	0.00***	0.01***	0.00***	0.00***
Y	0.01***	0.00	0.03***	–0.01**
W1	–0.04***	–0.05***	–0.04***	–0.03***
W2	–0.00	–0.00	0.01***	–0.03***
W3	0.01***	0.00***	0.02***	0.01***
W4	–0.01***	0.01	–0.02***	–0.01***
Intercept	0.16	0.20***	0.13***	0.19***
Cost share equation for labour				
ly1	0.03***	0.07***	0.01***	0.03***
w1	–0.00***	0.02***	–0.01***	0.02***
w2	0.01***	0.01***	0.00	0.01***
w3	0.01***	0.00	0.01***	0.00***
t	0.00***	–0.00	0.00***	–0.00**
Y	–0.03***	–0.03***	–0.01***	–0.04***
W1	0.05***	0.06***	0.07***	0.03***
W2	0.04***	0.04***	0.05***	0.05***
W3	–0.07***	–0.06***	–0.08***	–0.05***
W4	0.01***	–0.01**	–0.01***	0.02***
Intercept	0.30***	0.36***	0.26***	0.36***
Cost share equation for energy				
ly1	0.00**	0.00**	–0.00	–0.01***
w1	–0.00**	–0.01**	–0.01***	–0.00***
w2	0.01***	0.00	0.01***	0.00***
w3	–0.00***	–0.01***	–0.00***	0.00***
t	–0.01***	–0.00***	–0.00	–0.00***
Y	0.00	0.00	0.01***	0.01***
W1	0.01***	0.01***	0.02***	0.01***
W2	–0.03***	–0.03***	–0.04***	–0.02***
W3	0.01***	0.01***	0.01***	0.01***
W4	0.01***	0.00	0.00	0.00***
Intercept	0.04***	0.04***	0.04***	0.03***

***, ** and * represent statistically significant at 1%, 5% and 10% level of significance.