Energy Demand Decomposition and CO2 Emissions

By

Akinsehinwa Sharimakin

October 2016, 34th USAEE/IAEE North American Conference, Tulsa

A.Sharimakin@lboro.ac.uk

Loughborough University

Outline

- Background and Aims
- Research Contributions
- Methodology and Data
- Empirical Results
- Conclusion

Background and Aims

The increasing trend in global energy use and energy-related CO_2 emissions have initiated serious concern about energy security and increasing greenhouse gases.

Substitution of capital for energy arising from an increase in energy taxes as been regarded as a lasting solution particularly in the production settings.

……although, the substitution possibilities between inputs provide insightful information of the likely effect a change in relative input prices, but not the complete picture of input adjustment. The output effect represents a more complete picture of input adjustments (Chamber, 1982).

Therefore, this study decomposes changes in energy input demand into substitution and output effects and examines the implications of these effects on CO_2 emissions.

Loughborough University

Research Contributions

There is an in depth literature on substitution possibilities among factor inputs. More recently, Tovas and Iglesias (2013, C), Kim and Heo (2013, S), Haller and Hyland (2014, S) Lin and Ahmad (2016, S).

But, only a few studies (Kako, 1978; Chamber, 1982; Kim, 1987; Morakinyo et al., 2016) have analysed both the substitution and output effects arising from changes in relative input prices.

….however, none of the studies have empirically investigated the implications of the substitution and output effects on energy use or energy-related CO2 emissions.

Moreover, this is the first study (to the best of my understanding) that analyses the substitution possibilities among production factors with a Multilevel Model.

Methodology

Given the hierarchical structure of our data where industries are nested in countries for a number of years, this study employs a 3-level multilevel translog cost model to analyse factors input substitution possibilities with capital, labour, energy and material as inputs.

The estimated model is specified as follows:

$$\ln\frac{C_i}{w_m} = \alpha_0 + \alpha_q \ln q_t + \frac{1}{2}\alpha_{qq}\ln q_t^2 + \sum_{j=1}^{3}\delta_i \ln q_t \ln\frac{w_{ij}}{w_m} + \sum_{j=1}^{3}\alpha_i \ln\frac{w_{ij}}{w_m} + \frac{1}{2}\sum_{j=1}^{3}\sum_{i=1}^{3}\alpha_{ij}\ln\frac{w_{ij}}{w_m}\ln\frac{w_{ij}}{w_m} + \alpha_t t + \frac{1}{2}\alpha_{tt}t^2 + \alpha_{qt}\ln q_t\, t + \sum_{j=1}^{3}\varphi_i \ln\frac{w_{ij}}{w_m}t + \alpha_Y \ln Y + \alpha_{qY}\ln q_t \ln Y_t + \sum_{J=1}^{4}\alpha_{jY}\ln\frac{w_{ij}}{w_m}\ln Y_t + \alpha_{tY}\ln Y_t\, t + \sum_{J=1}^{4}\alpha_{JW}\ln W_J + \sum_{J=0}^{4}\alpha_{qW}\ln q_t \ln W_J + \frac{1}{2}\sum_{j=0}^{3}\sum_{J=0}^{4}\beta_i \ln\frac{w_{ij}}{w_m}\ln W_J + \sum_{J=0}^{4}\alpha_{tW}\ln W_J\, t + s_j + \varepsilon_{ij} \qquad (1)$$

where $\forall i, j = k, l, e\,;\quad \forall i, J = K, L, E, M$ and $\varepsilon_{ij} = u_j^{(3)} + u_{ij}^{(2)} + \epsilon_{ijt}$

Loughborough University

Methodology continues……..

From Eq. (1), this study employs the Allen-Uzawa (ES), Cross-price elasticity and Morishima (ES) to measure the elasticities of substitution between factors input. See Broadstock et al. (2007) for their formulas and relationships.

Slutsky equation is used to decompose producer's reaction to changes in energy prices into substitution and output effects using the uncompensated Marshallian and compensated Hicksian demand functions.

uncompensated demand function: $x_k = h_k(\mathbf{w}'q) \rightarrow m_k(\mathbf{w}', C) = h_k(\mathbf{w}', q(w'C))$.

Hicksian demand at production q is equal to Marshallian demand at cost *C*:

$$h_k(\mathbf{w}'q) = m_k(\mathbf{w}', c(w'q)).$$

by taking the derivative of the above equation w.r.t.$\boldsymbol{w}_i$ and substituting $x_k = h_k(\mathbf{w}'q)$ for $\frac{\partial c(\mathbf{w}'q)}{\partial w_k}$ we results at a Slutsky substitution and output effects of a change in energy price:

$$\frac{\partial m_k(\mathbf{w}'C)}{\partial w_k} = \frac{\partial h_k(\mathbf{w}',q)}{\partial w_k} - \frac{\partial m_k(\mathbf{w}'C)}{\partial c} m_k.$$

Which can be written in Mundlak (1968) elasticity form: $\eta_{ij} = \eta_{ij}^{c} - S_j \eta_{iC}$

Loughborough University

Methodology continues……..

A 3-level multilevel model is also employs to analyse the implications of energy demand decomposition on CO2 emissions. Estimated model is specified as follows:

$$co_{ijt} = CR_j'\gamma + X_{ij}'\delta + t_{ijt}' + u_j^{(3)} + u_{ij}^{(2)} + \epsilon_{ijt} \quad (2)$$

where $t = 1, \ldots., T_{ij}$, $i = 1, \ldots\ldots, M_j$ and $j = 1, \ldots\ldots, M$. co_{ijt} denotes the CO2 emissions for industry *i* in country *j* in time period *t* which is related to a vector of country-level explanatory variables *CR*, and industry-level explanatory variables *X*. *t* indicates year dummies. The error terms are assumed to be *IID* with zero mean and their respective variances.

Data

This study is based on a sample of 34 industries across 29 European countries over a period of 1995 – 2007. Temperature and exchange rate (US$) were taken from High Resolution Gridded Dataset and Tyndall, and Penn World Table (PT 7.1) respectively. All other series were obtained from World Input-Output Database (WIOD).

Raw data were in nominal values of national currency and converted into constant values using price indices (1995=100). Thereafter, using exchange rate PPP to convert them into US$.

CO_2 emissions in Gg (kt), energy use is in TJ, output is measured as gross output, temperature is measured as average annual temperature and employees are in thousand. Energy price is computed as the ratio of energy expenditure to energy use. Capital price is the ratio of capital compensation to real fixed capital stock. Labour price is the ratio of labour compensation to numbers of person engaged and material price is the ratio of material expenditure to material inputs.

Empirical Results

Table 1. Allen-Uzawa and Morishima Elasticities

capital		Labour		Energy	
σ_{KL}^{AES}	0.377*** [0.003]	σ_{LK}^{AES}	0.377*** [0.003]	σ_{EK}^{AES}	1.780*** [0.000]
σ_{KE}^{AES}	1.780*** [0.000]	σ_{LE}^{AES}	2.805*** [0.000]	σ_{EL}^{AES}	2.805*** [0.000]
σ_{KL}^{MES}	0.805*** [0.029]	σ_{LK}^{MES}	0.768*** [0.026]	σ_{EK}^{MES}	1.009*** [0.048]
σ_{KE}^{MES}	1.156*** [0.098]	σ_{LE}^{MES}	1.193*** [0.098]	σ_{EL}^{MES}	1.599*** [0.063]

Table 2. Own and cross-price elasticity of substitution

capital		Labour		Energy	
η_{KK}	-0.703*** [0.021]	η_{LK}	0.065*** [0.003]	η_{EK}	0.306*** [0.030]
η_{KL}	0.113*** [0.011]	η_{LL}	-0.692*** [0.000]	η_{EL}	2.837*** [0.046]
η_{KE}	0.065*** [0.006]	η_{LE}	0.103*** [0.006]	η_{EE}	-1.091*** [0.048]

Table 3. Energy demand decomposition: changes in energy prices

Substitution effect	-0.0046
Output effect	-0.0002

Empirical Results continues……….

Table 4. Decomposition effects on CO_2 emissions

Variables	Model 1	Model 2
Fixed part:		
Constant	-1. 802*** [0.306]	-2.157*** [0.308]
Industry – level variables		
Substitution effect	–	-1.709*** [0.116]
Output effect	–	-0.174*** [0.065]
Energy	0.243*** [0.008]	–
Output	0.111*** [0.019]	0.297*** [0.019]
Output squared	-0.009*** [0.001]	-0.017*** [0.001]
Employee	0.112*** [0.013]	0.151*** [0.014]
Country – level variables		
Temperature	-0.117*** [0.023]	-0.128*** [0.024]
Energy	0.576*** [0.035]	0.487*** [0.036]
Output	0.084*** [0.021]	0.211*** [0.021]
Employee	0.475*** [0.043]	0.601*** [0.043]
Random part:		
σ_V^2	0.225** [0.086]	0.192** [0.079]
σ_u^2	2.357*** [0.113]	3.021*** [0.142]
σ_ε^2	0.073*** [0.001]	0.075*** [0.001]
Intra-class correlation	0.085** [0.029]	0.058** [0.023]

Loughborough University

Conclusion

- Energy and non-energy inputs are substitutes.

- The European production sector CO_2 emissions are inversely related to both own substitution and output effects arising from an increase in energy prices.

- The substitution effects arising from an increase in energy prices dominate the output effects. This suggests that in the long run, improvement in the production technology such as energy efficiency arising from economies of scale without being supported by an increase in energy price would appear as a limited mean of reducing CO_2 emissions of the production sector.

Loughborough University

Thank You!