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Capital-Energy Relationships: An Analysis of Three Panel Data Estimation Methods

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According to Saunders (2000), the design of policies that aim to reduce energy consumption in the industrial sector via taxes requires knowledge of the Elasticity of Substitution (EoS) between capital and energy. If it is negative, then policies must encourage technological diffusion. However, if the elasticity is positive, taxes could then be used to reduce energy consumption

Literature Review

- It was argued that the omission variable bias was related with substitutability in energy and capital, Berndt and Wood (1979)
- Apostolakis (1990) argued that substitutability associated with long run adjustments in capital-energy (K-E) was related to the use of panel data settings.
- Frondel and Schmidt (2002) pointed out that none of these arguments were important. Under certain circumstances, the elasticities obtained by the Translog Cost Function ended up being close to the ratio of factor costs and total cost, and therefore, the (TCF) cannot provide reliable estimates.

Objectives

To use a panel data setting to estimate three models, computing EoS capital-energy across industries and also controlling for technological change by using two kinds of capital. In order to do so,

- first, the Thomsen's methodology is extended to be applied to a panel data context developing a new estimation method applied jointly with the GMM-SYS to deal with the dynamics of the system.
- Second, an ECM is estimated by using a Cobb-Douglas production function;
- Finally, a Translog cost function with three and four factors was applied to check if the results are robust to an omitted variable bias (as claimed by Berndt and Wood (1979)).

Translog cost function (two steep procedure)

The TCF is a second order approximation of $C(p, y, \tilde{t})$. When the expansion point is equal to zero and the derivatives are identified with β, we have

$\ln C \equiv$

$\beta_0 + \sum_{i=1}^{N} \beta_i \ln p_i + \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \beta_{ij} \ln p_i \ln p_j + \beta_{\tilde{t}} \tilde{t} + \frac{1}{2} \beta_{\tilde{t}\tilde{t}} \tilde{t}^2 +$
$\beta_y \ln y + \frac{1}{2} \beta_{yy} (\ln y)^2 \sum_{i=1}^{N} \beta_{iy} \ln p_i \ln y + \sum_{i=1}^{N} \beta_{i\tilde{t}} \tilde{t} \ln p_i + \beta_{y\tilde{t}} \tilde{t} \ln y$

Where p, y and $\tilde{t}$ stand for factor prices, output and technology. The subscripts i and j stand for factors.

This is a two step procedure that follows Fuss(1977). Therefore, we have the next production function
$Y = f(coal, electricity, natural$
$gas, oil, K_1(buildings), K_2(machinary),$
$L(labour), M(intermediate\ M)$

In panel data context

$\beta_0 = \sum_{h=1}^{H} \beta_{0_h}, \beta_i = \sum_{h=1}^{H} \beta_{i_h}, \beta_{\tilde{t}} = \sum_{h=1}^{H} \beta_{\tilde{t}_h}, \beta_{\tilde{t}\tilde{t}} = \sum_{h=1}^{H} \beta_{\tilde{t}\tilde{t}_h}, \beta_y = \sum_{h=1}^{H} \beta_{y_h},$

$\beta_{yy} = \sum_{h=1}^{H} \beta_{yy_h}, \beta_{iy} = \sum_{h=1}^{H} \beta_{iy_h}, \beta_{i\tilde{t}} = \sum_{h=1}^{H} \beta_{i\tilde{t}_h}, \beta_{y\tilde{t}} = \sum_{h=1}^{H} \beta_{y\tilde{t}_h}$

where subscripts h stands for industry h

Panel data

The dataset comprises eight industries with the highest energy consumption of the United Kingdom (UK) economy from 1970 to 2006. It was obtained from the Economic and Social data Service and the National Statistics for the UK. The variables comprise the investment in R&D for energy intensity, the value of output, factors and its prices.

Elasticities defined as follows

$$\eta_{i_h p_{j_h}} = \frac{\partial \ln i_h}{\partial \ln p_{j_h}} = \frac{\beta_{ij}}{s_{i_h}} + s_{j_h}$$

$$\eta_{i_h p_{i_h}} = \frac{\beta_{ii}}{s_{i_h}} + s_{i_h} - 1.$$

Where the subscript $_h$ denotes industry $_h$.

The Leontief cost function (long run)

$C = y\left[\sum_{i=1}^{N}\sum_{j=1}^{N}\alpha_{ij}(p_i p_j)^{0.5}\right] + \tau_{\tilde{t}\tilde{t}}\sum_{i=1}^{N}(p_{i\tilde{t}})\tilde{t}y,$

The input-output equations are estimated by the ISUR method

$\frac{i_{ht}}{y_{ht}} = a_{i_{ht}} = \sum_{j=1}^{N}\alpha_{ij}(p_{j_{ht}}/p_{i_{ht}})^{0.5} + \tau_{\tilde{t}\tilde{t}_h}$

Notice that for panel data

$\tau_{\tilde{t}\tilde{t}} = \sum_{h=1}^{H}\tau_{\tilde{t}\tilde{t}_h}$

Elasticities defined as follows

$$\eta_{i_h p_{j_h}} = \frac{\partial i_h}{\partial p_{i_h}} \frac{p_{j_h}}{C} = \frac{1}{2} \frac{\alpha_{ij} (p_{i_h} / p_{j_h})^{-0.5}}{a_{i_h}}$$

$$\eta_{i_h p_{i_h}} = \frac{-1/2 \sum_{j=1, j \neq i} \alpha_{ij} (p_{i_h} / p_{j_h})^{-0.5}}{a_{i_h}}$$

Sort run Leontief cost function

Following Thomsen (2000), the link between short and long run is through the price of the demand function of the long run value of capital.

Moreover, energy demand adjustment in the short run depends on the investment in capital which will be adjusted fully only in the long run. Therefore this stickiness implies a dynamic adjustment cost.

- The first order condition is a difference equation that can be written as follows
$\Delta\check{K}_{\bar{k}_{ht}} = \psi\Delta\check{K}^{*}_{\bar{k}_{ht}} + \phi(\check{K}^{*}_{\bar{k}_{ht-1}} - \check{K}_{\bar{k}_{ht-1}})$
where $\psi = (1 - \mu_1(1 - \lambda_2))$, $\phi = 1 - \mu_1$ and μ_1 is assumed to be the stable root of the difference equation, ϕ is the speed of adjustment coefficient and Δ denotes the first difference operator. Moreover, $\bar{k}$ denotes different types of capital.

The system of input-output equations along with the capital motion equation have to be estimated,
$\frac{i_{ht}}{y_{ht}} = a_{i_{ht}} = \sum_{j=1}^{N} \alpha_{ij} (p_{j_{ht}} / p_{i_{ht}}^{LR})^{0.5} + \tau_{\tilde{t}\tilde{t}_h}$
$\Delta \check{K}_{\bar{k}_{ht}} = \psi \Delta \check{K}^{*}_{\bar{k}_{ht}} + \phi(\check{K}^{*}_{\bar{k}_{ht-1}} - \check{K}_{\bar{k}_{ht-1}})$
The next vectors are proposed

$$
\begin{aligned}
\tilde{S}_{i_{ht}} &= (a_{1_{11}}, .., a_{i_{ht}}, .., a_{N_{HT}}, \frac{\Delta K_{1_{11}}}{y_{11}}, .., \frac{\Delta K_{1_{ht}}}{y_{ht}}, ..., \frac{\Delta K_{\bar{k}_{HT}}}{y_{HT}})', \\
\frac{\hat{K}^{*}_{\bar{k}_{ht}}}{y_{ht}} &= (0, 0, 0, ..., \frac{K^{*}_{1_{11}}}{y_{11}}, ..., \frac{K^{*}_{1_{ht}}}{y_{ht}}, ..., \frac{K^{*}_{\bar{k}_{HT}}}{y_{HT}})', \\
\frac{\hat{K}_{\bar{k}_{h(t-1)}}}{y_{ht}} &= (0, 0, 0, .., \frac{K_{1_{10}}}{y_{11}}, ..., \frac{K_{1_{1(t-1)}}}{y_{ht}}, ..., \frac{K_{\bar{k}_{H(T-1)}}}{y_{HT}})'.
\end{aligned}
$$

Arrellano,Bond and Blundell

To estimate the short run input-ouput equations, the new short run equation can be written as

$$\tilde{S}_{i_{ht}} = \phi_h\left(\frac{\hat{K}^*_{\bar{k}_{ht-1}}}{y_{ht}} - \frac{\hat{K}_{\bar{k}_{ht-1}}}{y_{ht}}\right) + \tilde{F}_{i_{ht}}\nu + \tilde{\epsilon}_{i_{ht}}$$

where $\tilde{F}_{i_{ht}} = \left[\tilde{X}_{i_{ht}}, D_{ht}, \frac{\Delta K^*_{\bar{k}_{ht}}}{y_h}\right]$ and $\nu = (\tilde{\alpha}, \tilde{\tau}_{\tilde{t}\tilde{t}_h}, \psi)'$. Notice that $\tilde{X}_{i_{ht}}$ is used to stress that the equations referring to the flexible factors have been modified by substituting out the shadow prices equation

Error Correction model

Elasticity of Technical Substitution
$TES_{i_h j_h} = -\frac{\partial i_h}{\partial j_h}\frac{j_h}{i_h} = \frac{\partial \ln i_h}{\partial \ln j_h}$
Assuming a Cobb-Douglas production function and that the factors $1, 2, .., N$ are cointegrated an autoregressive distributed lag model, ARDL(1,1), can be specified as follows
$\ln E_{ht} = \Psi_1 V_{ht} + \Psi_2 V_{h(t-1)} + \phi \ln E_{h(t-1)} + A_h + \xi_{ht}$,here
$V_{ht} = (\ln 1_{_{ht}}, \ln 2_{_{ht}}, \ln 3_{ht}, .., \ln(N-1)_{ht}, \ln \tilde{t}_{ht}, \ln y_{ht})'$ and
$\Psi_1 = (\tilde{\eta}_{1_h}, ..., \tilde{\eta}_{(N-1)_h}, \tilde{\eta}_{\tilde{t}_h}, \theta_h)'$.
Moreover, expression it can be reparameterized into an ECM framework as follows
$\Delta \ln E_{ht} = \Psi_1 \Delta V_{ht} + \Pi V_{h(t-1)} + (\phi - 1) \ln E_{h(t-1)} + A_h + \xi_{ht}$
where $\Pi = \Psi_1 + \Psi_2$

Translog cost function parameters(KLEM)

β_{EE}	0.0066	(0.0072)	$\beta_{K_2\tilde{t}_5}$	0.0134***	(0.0035)
β_{EK_1}	-0.0249***	(0.0064)	$\beta_{K_2\tilde{t}_6}$	0.0103***	(0.0031)
β_{EK_2}	-0.0294***	(0.0070)	$\beta_{K_2\tilde{t}_7}$	-0.0061	(0.0043)
β_{EL}	0.01420**	(0.0058)	$\beta_{K_2\tilde{t}_8}$	0.0050	(0.0039)
$\beta_{K_1K_1}$	0.0759***	(0.0130)	$\beta_{L\tilde{t}_1}$	-0.0088***	(0.0031)
$\beta_{K_1K_2}$	-0.0456***	(0.0107)	$\beta_{L\tilde{t}_2}$	-0.0064	(0.0046)
β_{K_1L}	0.0124	(0.0080)	$\beta_{L\tilde{t}_3}$	-0.0017	(0.0037)
$\beta_{K_2K_2}$	0.1109***	(0.0175)	$\beta_{L\tilde{t}_4}$	0.0172***	(0.0045)
β_{K_2L}	-0.0279***	(0.0090)	$\beta_{L\tilde{t}_5}$	0.0091***	(0.0035)
β_{LL}	0.0267***	(0.0094)	$\beta_{L\tilde{t}_6}$	-0.0028	(0.0033)
$\beta_{E\tilde{t}_1}$	0.0003	(0.0029)	$\beta_{L\tilde{t}_7}$	0.0035	(0.0043)
$\beta_{E\tilde{t}_2}$	0.0042	(0.0044)	$\beta_{L\tilde{t}_8}$	0.0033	(0.0037)
$\beta_{E\tilde{t}_3}$	0.0073**	(0.0035)	β_{Ey_h}	8DV	
$\beta_{E\tilde{t}_4}$	0.0002	(0.0045)	$\beta_{K_1y_h}$	8DV	
$\beta_{E\tilde{t}_5}$	0.0021	(0.0034)	$\beta_{K_2y_h}$	8DV	
$\beta_{E\tilde{t}_6}$	-0.0012	(0.0026)	β_{Ly_h}	8DV	
$\beta_{E\tilde{t}_7}$	0.0005	(0.0040)	β_{yy_h}	8DV	
$\beta_{E\tilde{t}_8}$	0.0001	(0.0038)	$\beta_{\tilde{t}t_h}$	8DV	

Elasticities(KLEM)

$\eta_{K_{1_1}p_{E_1}}$	-0.1646***	(0.0464)	$\eta_{K_{2_1}p_{E_1}}$	-1.7064***	(0.4598)
$\eta_{K_{1_2}p_{E_2}}$	-0.2388***	(0.0668)	$\eta_{K_{2_2}p_{E_2}}$	-1.1845***	(0.3466)
$\eta_{K_{1_3}p_{E_3}}$	-0.1900***	(0.0593)	$\eta_{K_{1_3}p_{E_3}}$	-0.4697***	(0.1753)
$\eta_{K_{1_4}p_{E_4}}$	-0.1592***	(0.0437)	$\eta_{K_{1_4}p_{E_4}}$	-2.6993***	(0.6982)
$\eta_{K_{1_5}p_{E_5}}$	-0.2726***	(0.0735)	$\eta_{K_{1_5}p_{E_5}}$	-2.2466***	(0.5657)
$\eta_{K_{1_6}p_{E_6}}$	-0.1730***	(0.0477)	$\eta_{K_{1_6}p_{E_6}}$	-2.3240***	(0.6001)
$\eta_{K_{1_7}p_{E_7}}$	-1.4845***	(0.3883)	$\eta_{K_{1_7}p_{E_7}}$	-1.4322***	(0.3475)
$\eta_{K_{1_8}p_{E_8}}$	-0.2249***	(0.0608)	$\eta_{K_{1_8}p_{E_8}}$	-2.4585***	(0.6472)

Elasticities KLE

$\eta_{K_{1_1}p_{E_1}}$	-0.0820	(0.2754)	$\eta_{K_{2_1}p_{E_1}}$	-0.6185	(2.9585)
$\eta_{K_{1_2}p_{E_2}}$	-0.1168	(0.3843)	$\eta_{K_{2_2}p_{E_2}}$	-0.2903	(2.2765)
$\eta_{K_{1_3}p_{E_3}}$	-0.0778	(0.3869)	$\eta_{K_{2_3}p_{E_3}}$	0.0633	(1.0108)
$\eta_{K_{1_4}p_{E_4}}$	-0.0878	(0.2669)	$\eta_{K_{2_4}p_{E_4}}$	-1.1789	(4.6816)
$\eta_{K_{1_5}p_{E_5}}$	-0.1193	(0.3809)	$\eta_{K_{2_5}p_{E_5}}$	-0.6220	(2.5815)
$\eta_{K_{1_6}p_{E_6}}$	-0.0865	(0.2822)	$\eta_{K_{2_6}p_{E_6}}$	-0.7466	(3.1930)
$\eta_{K_{1_7}p_{E_7}}$	-0.4105	(1.1970)	$\eta_{K_{2_7}p_{E_7}}$	-0.3601	(1.3720)
$\eta_{K_{1_8}p_{E_8}}$	-0.1263	(0.3804)	$\eta_{K_{2_8}p_{E_8}}$	-0.7608	(3.4683)

Parameters Leontief Cost function(Long run)

α_{EE}	-0.0077	(0.0119)
α_{EK_1}	0.0252***	(0.0089)
α_{EK_2}	0.0251**	(0.0105)
α_{EL}	0.0115*	(0.0064)
α_{EM}	-0.0288***	(0.0095)
$\alpha_{K_1K_1}$	-0.0641**	(0.0260)
$\alpha_{K_1K_2}$	0.0937***	(0.0178)
α_{K_1L}	-0.0812***	(0.0112)
α_{K_1M}	0.1523***	(0.0196)
$\alpha_{K_2K_2}$	-0.0985	(0.0741)
α_{K_2L}	0.0706**	(0.0327)
α_{K_2M}	0.2235***	(0.0450)
α_{LL}	0.2772***	(0.0212)
α_{LM}	0.0065	(0.0203)
α_{MM}	0.2607***	(0.0360)
$\tau_{\overline{H}_1}$	0.0133***	(0.0030)
$\tau_{\overline{H}_2}$	0.0060**	(0.0030)
$\tau_{\overline{H}_3}$	-0.0003	(0.0040)
$\tau_{\overline{H}_4}$	0.0345***	(0.0040)
	0.0019***	(0.0030)

Elasticities LCF(Long run)

$\eta_{K_{1_1} p_{E_1}}$	0.0962***	(0.0339)	$\eta_{K_{2_1} p_{E_1}}$	0.0430**	(0.0180)
$\eta_{K_{1_2} p_{E_2}}$	0.0918***	(0.0324)	$\eta_{K_{2_2} p_{E_2}}$	0.0415**	(0.0174)
$\eta_{K_{1_3} p_{E_3}}$	0.0980***	(0.0345)	$\eta_{K_{2_3} p_{E_3}}$	0.0424**	(0.0177)
$\eta_{K_{1_4} p_{E_4}}$	0.0852***	(0.0300)	$\eta_{K_{2_4} p_{E_4}}$	0.0398**	(0.0166)
$\eta_{K_{1_5} p_{E_5}}$	0.1028***	(0.0362)	$\eta_{K_{2_5} p_{E_5}}$	0.0436**	(0.0183)
$\eta_{K_{1_6} p_{E_6}}$	0.0946***	(0.0334)	$\eta_{K_{2_6} p_{E_6}}$	0.0424**	(0.0177)
$\eta_{K_{1_7} p_{E_7}}$	0.1035***	(0.0365)	$\eta_{K_{2_7} p_{E_7}}$	0.0394**	(0.0165)
$\eta_{K_{1_8} p_{E_8}}$	0.0928***	(0.0327)	$\eta_{K_{2_8} p_{E_8}}$	0.0412**	(0.0172)

Parameters LCF (Short run)

ψ	-2.0398***	(0.5532)
ϕ_1	-1.2674**	(0.7531)
ϕ_2	-0.8822***	(0.1486)
ϕ_3	2.9010	(1.8062)
ϕ_4	-0.9755	(1.0301)
ϕ_5	-1.8862**	(0.8258)
ϕ_6	-0.2544	(0.4848)
ϕ_7	2.2260	(1.7938)
ϕ_8	-2.2446*	(0.4364)
$\tilde{\alpha}_{EE}$	-0.0101	(0.0286)
$\tilde{\alpha}_{EK_1}$	0.0454*	(0.0266)
$\tilde{\alpha}_{EK_2}$	0.0052	(0.0396)
$\tilde{\alpha}_{EL}$	0.0225**	(0.0112)
$\tilde{\alpha}_{EM}$	-0.0379*	(0.0213)
$\tilde{\alpha}_{K_1K_1}$	-0.1238	(0.0987)
[illegible]	0.1472***	(0.0387)

Parameters LCF (Short run) cont.

$\tilde{\alpha}_{K_2K_2}$	-0.1078	(0.2624)
$\tilde{\alpha}_{K_2L}$	0.0661	(0.0978)
$\tilde{\alpha}_{K_2M}$	0.2027	(0.1418)
$\tilde{\alpha}_{LL}$	0.2865***	(0.0556)
$\tilde{\alpha}_{LM}$	0.0142	(0.0548)
$\tilde{\alpha}_{MM}$	0.2752**	(0.0930)
$\tilde{\tau}_{\bar{u}_1}$	0.0136**	(0.0060)
$\tilde{\tau}_{\bar{u}_2}$	0.0055	(0.0113)
$\tilde{\tau}_{\bar{u}_3}$	-0.0001	(0.0074)
$\tilde{\tau}_{\bar{u}_4}$	0.0343***	(0.0116)
$\tilde{\tau}_{\bar{u}_5}$	-0.0096	(0.0099)
$\tilde{\tau}_{\bar{u}_6}$	0.0047	(0.0060)
$\tilde{\tau}_{\bar{u}_7}$	0.0040	(0.0141)
$\tilde{\tau}_{\bar{u}_8}$	0.0127***	(0.0044)
Arellano-Bond test for AR(1)	-1.76	$P-value$ =0.079
Arellano-Bond test for AR(2)	-0.22	$P-value$ =0.827

Elasticities LCF (short run)

$\eta_{K_{1_1} p_{E_1}}$	0.1714*	(0.1005)	$\eta_{K_{2_1} p_{E_1}}$	0.0090	(0.0683)
$\eta_{K_{1_2} p_{E_2}}$	0.1648*	(0.0966)	$\eta_{K_{2_2} p_{E_2}}$	0.0087	(0.0656)
$\eta_{K_{1_3} p_{E_3}}$	0.1768*	(0.1036)	$\eta_{K_{2_3} p_{E_3}}$	0.0089	(0.0670)
$\eta_{K_{1_4} p_{E_4}}$	0.1533*	(0.0899)	$\eta_{K_{2_4} p_{E_4}}$	0.0083	(0.0630)
$\eta_{K_{1_5} p_{E_5}}$	0.1834*	(0.1075)	$\eta_{K_{2_5} p_{E_5}}$	0.0091	(0.0690)
$\eta_{K_{1_6} p_{E_6}}$	0.1686*	(0.0988)	$\eta_{K_{2_6} p_{E_6}}$	0.0089	(0.0671)
$\eta_{K_{1_7} p_{E_7}}$	0.2006*	(0.1176)	$\eta_{K_{2_7} p_{E_7}}$	0.0081	(0.0611)
$\eta_{K_{1_8} p_{E_8}}$	0.1672*	(0.0980)	$\eta_{K_{2_8} p_{E_8}}$	0.0086	(0.0652)

Tests for a common unit root

Null:common unit root process	Levels LLC	Levels Breitung t -stat	First differences LLC	First differences Breitung t -stat
E	-2.9319***	-2.0553**	-8.4115***	0.3418
K_1	-7.1817***	3.6483	-11.0840***	-8.9659***
K_2	-3.3529***	-0.7121	-4.3853***	-3.9532***
L	-3.6179***	-0.4884	-4.9019***	-4.0408***
M	2.6868	9.1312	-1.8084**	-4.5858***
$IR\&DEF$	-1.3199	-0.9862	-13.3448***	-4.6862***
y	0.3683	6.3036	-2.6277***	-4.8213***

Individual unit root test

	IPS	ADF -Fisher	PP -Fisher
Series in levels			
E	-1.9874**	30.5644**	52.4336***
K_1	-4.4823***	46.9313***	40.5891***
K_2	0.1891	22.4298	10.1968
L	-0.2756	19.9994	4.1604
M	6.4112	1.8019	3.8321
$IR\&DEF$	-1.5712**	21.6382	34.8997***
y	3.5521	18.3578	6.0799
First differences			
E	-7.8269***	113.9340***	91.8918***
K_1	-9.3789***	104.2700***	49.5041***
K_2	-3.7331***	46.5842***	43.4554***
L	-6.2217***	65.3152***	87.7057***

Pedroni (2004) test for cointegration

Alternative hypothesis: common autoregressive coefficients(within-dimension)	
Panel v -Statistic	2.0895**
Panel rho -Statistic	0.3065
Panel PP -Statistic	-2.8598***
Panel ADF -Statistic	0.3754
Alternative hypothesis: individual autoregressive coefficients (between-dimension)	
Group rho -Statistic	2.0007
Group PP -Statistic	-0.6011
Group ADF -Statistic	0.5506

Estimation results from the Error Correction model

$TES_{E_1K_{1_1}}$	0.4353*	(0.2557)	$TES_{E_1K_{2_1}}$	1.5887***	(0.3264)
$TES_{E_2K_{1_2}}$	0.0523	(0.2085)	$TES_{E_2K_{2_2}}$	1.4008**	(0.5624)
$TES_{E_3K_{1_3}}$	0.5039***	(0.1420)	$TES_{E_3K_{2_3}}$	-1.1477***	(0.4003)
$TES_{E_4K_{1_4}}$	0.0765	(0.1766)	$TES_{E_4K_{2_4}}$	1.4034***	(0.2960)
$TES_{E_5K_{1_5}}$	0.7657**	(0.3635)	$TES_{E_5K_{2_5}}$	4.1575***	(0.7003)
$TES_{E_6K_{1_6}}$	1.4190***	(0.3236)	$TES_{E_6K_{2_6}}$	1.0161***	(0.2634)
$TES_{E_7K_{1_7}}$	-0.2560	(0.2666)	$TES_{E_7K_{2_7}}$	0.2369	(0.7513)
$TES_{E_8K_{1_8}}$	0.1694	(0.1580)	$TES_{E_8K_{2_8}}$	-0.7160	(0.6258)
$TES^{LR}_{EK_1}$	0.1162	(0.3845)	$TES^{LR}_{EK_2}$	1.3924***	(0.5159)

Second unit root test

Null: Unit root (assumes common unit root process)	
Levin, Lin & Chu*	-19.1334***
Null: Unit root (assumes individual unit root process)	
ADF - Fisher Chi-square	481.4740***
PP - Fisher Chi-square	432.9090***

Conclusion

- There is complementarity when using the TCF while when using the GL, the conclusion was weak substitutability.
- Substitution between capital and energy is more limited when capital is invested in machinery than when it is invested in buildings.
- Particularly it will be more harmful for the industries of basic metals, chemical, transport equipment and machinery that are the ones that show stronger dependence between energy and capital.
- A better policy may be to encourage technological diffusion. Additionally, the GL also provide evidence that there is a rebound effect since the estimated coefficients are also positive.

Further Research

Using data to firm level may help to distinguish even further for which industries an increase of energy prices can be more harmful; however, there is still a pending issue about the proper way to measure the substitution among productive factors and this is an objective of future research.