The relationship between energy consumption and economic activity in EU-27 countries: testing the neutrality hypothesis

Vladimír Hajko[a]

[a] *Department of Economics, Faculty of Economics and Administration, Masaryk University, Lipová 507/41a, Brno, Czech Republic*

Abstract

The aim of the article is to test the 'neutrality hypothesis' between the energy consumption and the economic activity in the EU-27 countries. The evidence speaks for the rejection of the 'neutrality hypothesis' in favor of the 'growth hypothesis'. The results differ between the original and the new EU member countries. The original member countries exhibit tendency to increase their economic growth with energy savings. However, in case of the new member countries there seems to be a negative impact of energy savings on the economic growth. For sectoral energy consumption, the main drivers of the causality in the relationship are the residential sector, industry and services. The residential energy consumption savings appear to increase the economic growth in both original and new member countries. The role of the energy consumption savings in the industrial and services' sector differ. For the industrial sector, in the original member countries the energy consumption savings increase economic growth, while in the new member they may hinder the economic growth. In services, the energy consumption does not seem to have an impact in the original member countries, while in the new member countries the savings in energy consumption seem to degrade the economic growth.

Keywords: GDP, Energy use, EU-27, The 'growth hypothesis', The 'neutrality hypothesis'

JEL classification: O13, Q43

1. INTRODUCTION

The relationship between energy consumption and economic activity is the classical topic of the energy economy. As the literature reviews suggest (see e.g.

Email address: vladimir.hajko@mail.muni.cz (Vladimír Hajko)

Bohi and Zimmerman (1984), Dahl (1994), Keppler et al. (2007), Mahadevan and Asafu-Adjaye (2007), Sari and Soytas (2007) or Ozturk (2010)) it remains a lively topic even decades after the seminal work of Kraft and Kraft (1978) and is still considered a topic of fundamental importance (Chontanawat et al., 2008). The energy policy debates, in the recent period gaining the significant attention both by public and the politicians therefore call for the need of greater understanding of the underlying implications of the measures that are either under the consideration or already being employed. Examples of such public debates are the environmental concerns and consequent "pro-green" measures, including e.g. the post-Kyoto protocol policies[1], the energy conservation measures and regulations[2], or the shutdown of nuclear power plants (NPP) in Germany following the Fukushima NPP incident, considerably reducing the electricity generation supply. An example of the political action may be the introduction and the implementation of the 20-20-20[3] plan[4]. This plan already serves as a guideline for the implementation of the goals in the individual member countries. As such it requires the significant involvement of the regulations in the energy use. It is however unclear whether the policy makers in the EU and in the member states are aware of all the possible effects of such policies on the economy. This article intends to provide such an insight regarding the effects of the changes in the energy consmuption on the economy growth (measured by real GDP per capita).

As summarized e.g. in Ozturk (2010), the directions of causality between the energy consumption and economic growth can be described in four different hypotheses, each with vastly different policy implications. In brief, these four hypotheses consists of: the 'neutrality hypothesis', expecting no causality between the economic growth and energy consumption, implying neither the energy conservation or expansion policies will affect the economic growth and vice versa.

[1]Employing the emission trading and therefore introducing the total emission caps - that (to a certain extent given the difficulties of swift large-scale technology transitions) also represent the consumption cap

[2]E.g. well known case of the ban of incandescent light bulbs in the European market (by Commission Regulation (EC) No 244/2009), forcing a switch of the consumers' choice towards discharge lamps. Despite the wording of the document, labeling itself as "setting the ecodesign requirements" (for its aim to reduce the energy consumption and consequently some of the related carbon dioxide emissions), it should be noted the presence of toxic materials in the discharge lamps (most commonly mercury vapor, metal halides, phosphor, beryllium, cadmium, or thallium), represents a significant environmental concern and goes directly against the appeal of the United Nations Environment Programme (2009).

It is noteworthy this regulation was indeed only one of the first measures in the regulation of availability of technologies that are deemed "inefficient". Interested reader may find additional plans in the document of the European Commission COM(2006) 545: Communication from the Commission - Action Plan for Energy Efficiency: Realising the Potential

[3]With objectives of achieving 20% reduction in EU's Greenhouse Gas emissions, 20% energy share from renewable sources and 20% reduction in the consumption of primary energy by the year 2020.

[4]Set forth in the Communication from the Commission to the European Council and the European Parliament - an energy policy for Europe {SEC(2007) 12}/ COM/2007/0001 final

The opposite point of view represents the 'feedback hypothesis', expecting the mutual interdependence of the energy consumption and economic growth, and their joint determination and bi-directional causality. In such case, the policy implication need to take into the account the expected behavior of the economy given the specific form the relationship both for the design and for the effects of the proposed energy policy.

The remaining two hypotheses represent uni-directional causalities, either from the economic growth to the energy consumption (the 'conservation hypothesis') or from the energy consumption to the economic growth (the 'growth hypothesis'). The 'conservation hypothesis' implies the energy conservation plans may be implemented without the impacts on the economic growth. The 'growth hypothesis' considers the energy as necessary production factor and implies the reduction in the energy supply (and hence consumption) will (often) negatively affect the economic growth, or that the energy supply expansion policies may speed up the growth.

Even though the evidence for such 'energy-economy' relationships is mixed, even if comparing the "similar" countries, these can usually be attributed to the differences in the methodology applied, the selection of the data (it is sensible to assume some heterogeneity in the behavior in different sectors in the economy, and of course possible development or changes in the relationship in time) or the different dynamics (lag structure) employed (Masih and Masih, 1997). Even when accounting for the variety of possible explanatory variables as well as measures of growth, the topic is still worth attention for the policy makers. If for nothing else even the seemingly non-uniform answer of different aspects of the economy examined provides the reasoning for the different attention to different sectors (and different policy making for different countries).

The data availability is also an issue. Especially in Europe, where the era of centrally planned economies (CPE) affected the development of many states [5], the reasonable assumption on information capability of the past for the current development simply does not hold for but the very recent period (this may be in the range of 20 years or possibly less due to necessary post-transformation adjustments). Even with the efforts of international bodies like OECD, World Bank or Eurostat office, the data are rarely available both in sufficient sectoral and time detail. This limits the operating field of a researcher, and is also a reason this paper works only with the annual data for the EU-27 countries in the period of 1995-2010[6], even though the more detailed data in higher frequency

[5] As the results in Hajko (2012) indicate, in the analyses concerning the energy consumption development in the EU countries, the attention should be paid to the significant differences between the countries of EU-15 (original EU members) and the new member countries. The results also suggest the exclusion of Cyprus, Malta and Slovenia from a group of the new member countries (the options are therefore omitting these three countries in the analysis, incorporating them in the former group of EU-15 or possibly examining them in a third separate group).

[6] With this data range I assume that by the beginning of the examined period the transformation processes (including post-transformation recessions) in the formerly centrally planned economies were more or less finished. Also, the real GDP values are not available for all the

probably might be able to provide details that might remain unanswered in this analysis.

Nevertheless, given the fact that many such states are now European Union members, and despite their different historical and economical backgrounds, are facing the challenges of achieving the policy goals of the European Union in the energy sector (indeed, not only in the energy sector, but virtually in all fields of economic policy). In the scope of this article, the especially important is the goal of the Energy Policy for Europe (also known as the 20-20-20 plan) to achieve 20% reduction (EU-average) in energy consumption by the year 2020.

It is therefore the aim of this article to examine whether there is the same type of energy-economy relationship in the EU-27, and consequently, whether there may be some concerns regarding the implications of achieving this goal. The main hypothesis of the article is therefore to test whether the objective of the energy consumption reduction will not affect the economic growth (the 'neutrality hypothesis') or the decreases in energy consumption represent a potential benefit (or an obstacle) to economic growth (i.e. as per the 'growth hypothesis'). All the figures and tables in this article are my own.

2. THE DATA

The sources of the data were Eurostat statistics[7]. Data are in annual frequency. The graphical representation of the panel data is provided in the appendix.[8]

The data in levels were transformed to natural logarithms. The ADF tests[9] of the stationarity of the data were employed. In case of non-stationarity[10], the data were transformed to growth rates (the first differences of the natural logarithms). Due to a large number of estimation results, only the most important estimations will be shown[11].

countries in the sample for periods before 1995

[7]Tables Final energy consumption, by sector [tsdpc320], Real GDP per capita, growth rate and totals [tsdec100], Dataset Industry production index [sts_inprgr_a],

[8]Please note the Final energy consumptionfigures cover period 1990-2010 and the Real GDP per capita figures period of 1995-2010. Also note the "complicated behavior" of the post-transformation period (approx 1990-1995) especially in the new member countries

[9]ADF test relies (in the well-known form of $\triangle y_t = \beta_0 + \gamma t + (\phi - 1)y_{t-1} + \rho_1(\triangle y_{t-1}) + \ldots + \rho_{p-1}(\triangle y_{t-p+1}) + \epsilon_t$ (i.e. with up to p lags)) on observing whether the coefficient of y_{t-1} is significantly different from zero. In this case the lagged structure was obtained by sequential elimination of insignificant lags (starting from high number of lags) in order to avoid the problems with possible autocorrelation of the error term in the ADF test equation.

[10]It is noteworthy that in several cases, the more work should be done to deal with possible structural breaks (leading to signs of non-stationarity), namely in case of Greece, Portugal and Romania in case of the GDP variable, and Finland, Greece, Portugal and Spain in case of the energy consumption variable.

[11]Please note the asterisks displayed with p-values indicate significance levels (*, ** and *** indicate significance at 10%, 5% and 1% respectively)

3. THE MODEL

The principal methodology that will be applied in this paper follows the common approach in the literature, and focuses on the so-called Granger causality (Granger, 1969). This causality is employed to establish a manner of causality that remains unclear in the common regression analysis, i.e. the direction of the causality if observing the significance of the relation between the explained and the explanatory variables. The Granger causality is based on the assumption that events of the future cannot have an impact on (cannot cause) the events in the past. If the explanatory variables represent the events that happened in the past, the aforementioned assumption means the events in the past could not be caused by the events in the present (future) but rather the events in the past caused the current events.

To test the hypotheses of the Granger causality, the following equations are estimated:

$$\triangle y_t = \alpha + \sum_{i=1}^{m} \beta_i \triangle y_{t-i} + \sum_{j=1}^{n} \gamma_j \triangle e_{t-j} + time + D1 + u_t$$

$$\triangle e_t = \alpha + \sum_{i=1}^{m} \beta_i \triangle y_{t-i} + \sum_{j=1}^{n} \gamma_j \triangle e_{t-j} + time + D1 + u_t$$

where $\triangle y_t$ represents the growth rate of real GDP per capita, $\triangle e_{t-j}$ represents the growth rate of the final energy consumption, $time$ represents the time trend (in case of trend stationary variables) and $D1$ represents a dummy variable (in order to accommodate the possibility of a structural break following the global financial turmoil and starting the period of crisis) with value of 1 for years 2008-2010 and 0 otherwise[12] and the u_t represents the error term. Due to the limited number of time observations for each cross-sectional unit, the lag structure will be only modest (the most appropriate form seems to be with 1 lag, easily allowing to interpret the signs in the suspect relationship).

The estimations were done for the panel of the countries[13].

The procedure undertaken therefore consisted of the following steps: ADF test for the data in levels and in growth rates. In order to avoid possible negative impact of the non-stationary behavior, I have undertaken a further selection in the groups of countries for the panel estimates. Dynamic panel model estimations for following groups were performed: EU-27, EU-15 (original member countries), EU-12 (new member countries). Furthermore EU-11 (original member countries without Greece, Portugal, Spain, Finland), EU-8 (new member

[12] While we may argue the different choice of periods for the "structural change", or the representation of these with multiple dummy variables, the individual models did not respond significantly different with the inclusion of multiple dummy variables; furthermore, the problem with the matrix invertibility occurred with too many dummy variables.

[13] In case of panel estimations, dynamic panel data estimations were used, using the "system estimator" (Blundell and Bond, 1998) which seems to be the preferred choice in the applied literature.

countries without Cyprus, Malta, Slovenia, Romania) and EU-19 (EU-11 and EU-8).

4. ESTIMATION RESULTS

Given the objective of this article, it may be worth noting the possibility of existence of a cointegration relationship in some of the countries. Estimation of the Engle-Granger procedure for the individual countries, with the inclusion of the aforementioned dummy variable, indicates a possible existence of such a relationship in the France, Germany, Italy and Slovenia. It is however possible this relationship may be sensitive to the setting of structural break period(s). This may be the subject of a further examination, however due to the limit number of observations, it would be necessary to obtain the data in higher time frequency in order to avoid estimation difficulties.

To follow up on the testing of the main hypotheses: the estimations are done on the panels of the countries, with both unlimited and limited selection of the countries based on the stationarity tests. Consequently estimation is done for the individual sectors. For the sake of brevity (even though the results do not deviate greatly in the wider group) I present the sectoral estimations only on the limited panel of EU-19 (in order to avoid the possible influence of non-stationarity in some of the individual countries on the results).

As you may notice in the tables with estimation results, the results differ between the original and the new member countries, regardless if we omit the countries mentioned above or not. The main findings that should be noted are that for the panel of the countries (the European Union) the causality seems to be from the energy consumption to the GDP, but not vice versa (similar results as e.g. in Lee (2005), Lee (2006), Chontanawat et al. (2008), Narayan and Smyth (2008) or Narayan and Popp (2012)). This results would speak for the rejection of the 'neutrality hypothesis' in favor of the 'growth hypothesis'. However the causality effect seems to be more prominent in the original member countries[14]. This is more or less in line e.g. with the results of Chontanawat et al. (2008) who found that such a relationship may be observed with a greater proportion in OECD/developed countries than in the non-OECD/developing countries.

However, it should be noted that the original and the new member countries show differences in the sign of the effect of the change in energy consumption.[15] The negative sign of the original member countries (i.e. a similar result as in Narayan and Popp (2012) for G6 countries) would indicate that the policies

[14]The causality effect being either slightly positive or not-significant in the new member countries, depending on the size of the sample and sectoral consumption

[15]It is noteworthy to mention that while the Narayan and Smyth (2008)found the positive sign of such a relationship, implying the negative impact of energy consumption reduction in G7 countries, Narayan and Popp (2012) found for the group of G6 countries a negative sign, implying the energy conservation policies would not hamper (or it may even enhance) economic growth.

Table 4.1: Panel estimations with Energy explaining GDP, both groups

(Dynamic panel)	Energy explaining GDP		
	EU-27		
	coefficient	p-value	
GDP(-1)	0.0938	0.000	***
const	0.0374	0.000	***
D1	-0.0455	0.000	***
time	-0.0011	0.000	***
energy(-1)	-0.0908	0.000	***
EU8*(energy(-1))	0.1519	0.000	***
EU8	0.0233	0.000	***

(Dynamic panel)	Energy explaining GDP		
	EU-19		
	coefficient	p-value	
GDP(-1)	-0.0133	0.802	
const	0.0317	0.000	***
D1	-0.0543	0.000	***
time	-0.0003	0.324	
energy(-1)	-0.2121	0.000	***
EU8*(energy(-1))	0.3051	0.000	***
EU8	0.0227	0.000	***

Table 4.2: Panel estimations with Energy explaining GDP, per original and per new member countries

	(Dynamic panel) Energy explaining GDP					
	EU-15 ("original")			EU-12 ("new")		
	coefficient	p-value		coefficient	p-value	
GDP(-1)	0.0598	0.309		0.2801	0.060	*
const	0.0614	0.000	***	0.0279	0.025	**
D1	-0.0211	0.000	***	-0.0424	0.002	***
time	-0.0029	0.000	***	-0.0001	0.873	
energy(-1)	-0.1027	0.000	***	-0.1013	0.130	

	(Dynamic panel) Energy explaining GDP					
	EU-11			EU-8		
	coefficient	p-value		coefficient	p-value	
GDP(-1)	0.0166	0.828		0.1308	0.483	
const	0.0494	0.000	***	0.0071	0.750	
D1	-0.0312	0.000	***	-0.0637	0.000	***
time	-0.0018	0.000	***	0.0026	0.015	**
energy(-1)	-0.1471	0.000	***	-0.0510	0.540	

aiming at the reduction of the energy consumption (such as the 20-20-20 plan) would not hinder economic growth and may in fact prove beneficial in terms of faster economic growth. Such an observation in these (arguably "more developed/advanced") countries of the European Union probably lies in the higher innovation power in these countries, as opposed to the room for extensive source allocation in the countries where the lower costs of operations may be expected.

However, the inverse effect may happen in the new member countries. E.g. Lee (2005) argues that this possibility of economic growth slowdown due to energy conservation is the case for the developing countries regardless of whether they are transitory or permanent. Even though not all of the new member countries are considered "developing countries", their characteristics both in energy consumption (or more obviously in energy intensity) and economic level (e.g. measured by GDP per capita) might be considered closer to those of "developing" countries than to characteristics of the original EU countries. The reason of this pattern corresponds to the development in these countries even before the enlargment of the EU, when the new member countries more often (than their EU-15 counterparts) rely on attracting the more energy (and labor) intensive industries in order to increase their growth potential. The possibility of reallocation of the production into these countries may be the differentiating factor in the aforementioned energy-economy relationship. Lower costs of operation (being often the major driving force of companies' restructuring) may be achieved either with innovations such as improving the technology, providing the increased productivity per input factor unit (or the same output with less inputs), or with lower input factor costs in the emerging markets of "less developed" countries, however driving the input factor consumption higher.

Especially if we take a look at the sectoral energy consumption estimations, we can find some major differences contributing to such a behavior. While for the original member countries only industrial and residential energy consumption seem to be significant factor affecting economic growth, in the new member countries both these groups and services are influential. Unlike the industrial sector in the original member countries (negative sign), both the services and industrial energy consmuption exhibits positive sign in the new member countries. This means that energy conservation policies (if achieving energy savings in industrial sector) would prove beneficial in the original member countries, being not limiting and possibly even beneficial for the economic growth (though it is questionable whether the consumption restriction would induce more innovations). In the new member countries, the story is reversed. Energy conservation policies, if achieving savings in services and industrial sector, would hinder economic growth in the new member countries.

Furthermore, changes in the energy consumption in the residential sector exhibit negative sign in both groups. This would correspond to the much less-diversified pattern in the household behavior (rather than the arguably more dynamic and more willing to relocate or structure-change oriented behavior of the firms). In terms of the energy policy design in the individual EU countires, the main potential of the competition advantage gains or losses therefore probably lie elsewhere than in the residiential sector. It is also rather easy to affect the residential sector on the EU-wide level, e.g. by the household appliances design restrictions. Even though such policies inherently limit the consumers free will and probably limit the consumer's satisfaction, the evidence suggests the energy conservation policies aimed on the residential sector would not hinder economic growth and may even prove beneficial in terms of faster growth.

5. CONCLUSION

It is found that for the panel of EU countries changes in the growth rate of energy consumption Granger cause changes in the economic growth rate. For the European Union, the 'neutrality hypothesis' is rejected in favor of the 'growth hypothesis'. This corresponds to results in Lee (2005), Lee (2006), Chontanawat et al. (2008), Narayan and Smyth (2008) or Narayan and Popp (2012). However, it seems that the 'growth hypothesis' is different for the "more developed" countries (e.g. original EU member countries in this article, or G6 countries in Narayan and Popp (2012)) and the "less developed" countries (e.g. new EU member countries in this article or countries in Lee (2005, 2006)). In the "more developed" countries the energy conservation policies would not hinder economic growth and may in fact prove beneficial to faster economic growth. In the "less developed" countries the opposite applies and the energy conservation policies would probably hinder the economic growth.

In this article (in terms of the influence of energy consumption), not all sectors show the significance in the energy-economy relationship. Except for the "same story" for the residential sector, the results differ. The residential sector is not only significant in both old and new member countries, but also shows the negative sign in both groups (implying that energy savings in residential sector would not hinder economic growth but may be even beneficial for it. However, the energy conservation in services and industrial sector would probably restrict the economic growth in the new member countries.

In the original member countries the industrial sectors seems to be most influential. Furthermore, the results indicate that in these countries the energy consumption savings in industrial sector may even increase economic growth.

It seems the total energy consumption should be applied as an explanatory factor with some caution. Considering the richer results if applied in sectoral division, it seems as a good practice not to focus on the aggregate values (or at least not only) and instead to consider the different behavior of different sectors in both energy consumption analyses and in the energy conservation policy design.

Unified energy conservation policies therefore do not seem to be the good recipe for all the countries involved in them. Even though there may be political will to construct the common goals and objectives, different policy design for each of the groups should probably be considered. Care should be taken especially with the energy conservation policy implementations in the new member countries, especially regarding the influential sectors of services and industry. Furthermore, energy conservation plans and regulations should probably be constructed separately for the residential energy sector.

Table 4.3: Panel estimations with GDP explaining Energy, both groups

(Dynamic panel)	GDP explaining Energy		
	EU-27		
	coefficient	p-value	
energy(-1)	-0.0041	0.957	
const	0.0061	0.571	
D1	-0.0071	0.126	
time	0.0000	0.968	
GDP(-1)	0.0624	0.632	
EU8*(GDP(-1))	-0.1728	0.393	
EU8	-0.0006	0.936	
(Dynamic panel)	GDP explaining Energy		
	EU-19		
	coefficient	p-value	
energy(-1)	-0.1959	0.217	
const	-0.0162	0.298	
D1	-0.0204	0.000	***
time	0.0018	0.053	*
GDP(-1)	-0.0042	0.986	
EU8*(GDP(-1))	0.0383	0.906	
EU8	-0.0074	0.426	

Table 4.4: Panel estimations with GDP explaining Energy, per original and per new member countries

	(Dynamic panel) GDP explaining Energy					
	EU-15 ("old")			EU-12 ("new")		
	coefficient	p-value		coefficient	p-value	
energy(-1)	-1.0528	0.000	***	0.0185	0.941	
const	0.0872	0.000	***	-0.0374	0.124	
D1	0.0020	0.734		-0.0227	0.080	*
time	-0.0052	0.000	***	0.0032	0.024	**
GDP(-1)	0.0230	0.885		-0.0741	0.669	
	(Dynamic panel) GDP explaining Energy					
	EU-11			EU-8		
	coefficient	p-value		coefficient	p-value	
energy(-1)	-0.6616	0.005	***	-0.4216	0.371	
const	0.0397	0.004	***	-0.0869	0.013	**
D1	-0.0034	0.663		-0.0483	0.016	**
time	-0.0023	0.014	**	0.0066	0.002	***
GDP(-1)	-0.0968	0.556		0.0086	0.961	

Table 4.5: Panel estimations with sectoral energy consumption explaining GDP, EU-19

(Dynamic panel) Energy explaining GDP EU-19	coefficient	p-value	
GDP(-1)	-0.2509	0.339	
const	0.0345	0.006	***
EU8	0.0270	0.000	***
D1	-0.0476	0.000	***
time	-0.0005	0.382	
E_services(-1)	-0.0256	0.105	
E_industry(-1)	-0.1039	0.009	***
E_residential(-1)	-0.0382	0.049	**
E_transport(-1)	0.0426	0.606	
E_agricul(-1)	0.0052	0.735	
EU8*E_industry(-1)	0.1874	0.000	***
EU8*E_services(-1)	0.0629	0.001	***
EU8*E_residential(-1)	-0.1136	0.181	
EU8*E_transport(-1)	0.0886	0.437	
EU8*E_agricul(-1)	0.0115	0.799	

Table 4.6: Panel estimations, with GDP explaining sectoral energy consumption, EU-19

(Dynamic panel) Sectoral energy consumption explaining GDP EU-19							
	explaining E_services:				explaining E_industry:		
	coefficient	p-value			coefficient	p-value	
E_services(-1)	-0.1317	0.006	***	E_industry(-1)	-0.2114	0.364	
const	0.0149	0.752		const	-0.0399	0.126	
time	-0.0002	0.925		time	0.0034	0.024	**
D1	0.0205	0.062	*	D1	-0.0714	0.000	***
EU8	0.0166	0.420		EU8	-0.0049	0.839	
GDP(-1)	0.0339	0.973		GDP(-1)	-0.1801	0.776	
EU8*GDP(-1)	-0.1907	0.860		EU8*GDP(-1)	-0.2204	0.768	
	explaining E_residential:				explaining E_transport:		
	coefficient	p-value			coefficient	p-value	
E_residential(-1)	-0.2784	0.000	***	E_transport(-1)	-0.1041	0.208	
const	-0.0167	0.348		const	0.0330	0.001	***
time	0.0010	0.312		time	-0.0009	0.217	
D1	0.0310	0.000	***	D1	-0.0372	0.000	***
EU8	-0.0129	0.389		EU8	0.0184	0.000	***
GDP(-1)	-0.1038	0.817		GDP(-1)	-0.0527	0.659	
EU8*GDP(-1)	0.1845	0.753		EU8*GDP(-1)	0.2831	0.132	
	explaining E_agricul:						
	coefficient	p-value					
E_agricul(-1)	-0.1659	0.000	***				
const	-0.0688	0.128					
time	0.0039	0.129					
D1	-0.0049	0.767					
EU8	-0.0141	0.538					
GDP(-1)	0.2593	0.720					
EU8*GDP(-1)	-0.3416	0.714					

References

, 2009. Proceedings of the Governing Council/Global Ministerial Environment Forum at its twenty-fifth session, United Nations Environment Programme. Governing Council of the United Nations Environment Programme, Nairobi. UNEP/GC.25/17.

Blundell, R., Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. Journal of Econometrics 87, 115–143.

Bohi, D., Zimmerman, M., 1984. An Update on Econometric Studies of Energy Demand Behavior. Annual Review of Energy 9, 105–154.

Chontanawat, J., Hunt, L., Pierse, R., 2008. Does energy consumption cause economic growth?: Evidence from a systematic study of over 100 countries. Journal of Policy Modeling 30, 209–220.

Dahl, C., 1994. A Survey of Energy Demand Elasticities for the Developing World. Journal of Energy and Development 18, 1–48.

Granger, C., 1969. Investigating causal relations by econometric models and cross-spectral methods. Econometrica 36, 424–438.

Hajko, V., 2012. Changes in the Energy Consumption in EU-27 Countries. Review of Economic Perspectives 12, 3–21.

Keppler, J.H., Bourbonnais, R., Girod, J. (Eds.), 2007. The Econometrics of Energy Systems. PALGRAVE MACMILLAN.

Kraft, J., Kraft, A., 1978. On the relationship between energy and GNP. Journal of Energy and Development 3, 401–403.

Lee, C., 2005. Energy Consumption and GDP in Developing Countries: A Cointegrated Panel Analysis. Energy Economics 27, 415–427.

Lee, C., 2006. The causality relationship between energy consumption and GDP in G-11 countries revisited. Energy Policy 34, 1086–1093.

Mahadevan, R., Asafu-Adjaye, J., 2007. Energy consumption, economic growth and prices: a reassessment using panel VECM for developed and developing countries. Energy Policy 35, 2481–2490.

Masih, A.M.M., Masih, R., 1997. On the temporal causal relationship between energy consumption, real income, and prices: Some new evidence from Asian-energy dependent NICs based on a multivariate cointegration/vector error-correction approach. Journal of Policy Modeling 19, 417–440.

Narayan, P.K., Popp, S., 2012. The energy consumption-real GDP nexus revisited: Empirical evidence from 93 countries. Economic Modelling 29, 303–308.

Narayan, P.K., Smyth, R., 2008. Energy consumption and real GDP in G7 countries: New evidence from panel cointegration with structural breaks. Energy Economics 30, 2331–2341.

Ozturk, I., 2010. A literature survey on energy-growth nexus. Energy Policy 38, 340–349.

Sari, R., Soytas, U., 2007. The growth of income and energy consumption in six developing countries. Energy Policy 35, 889–898.

Appendix:

Appendix A. Graphical representation of the data in levels

Figure A.1: Real GDP per capita, original member countries (EU-15), 1996-2010, EUR per inhabitant

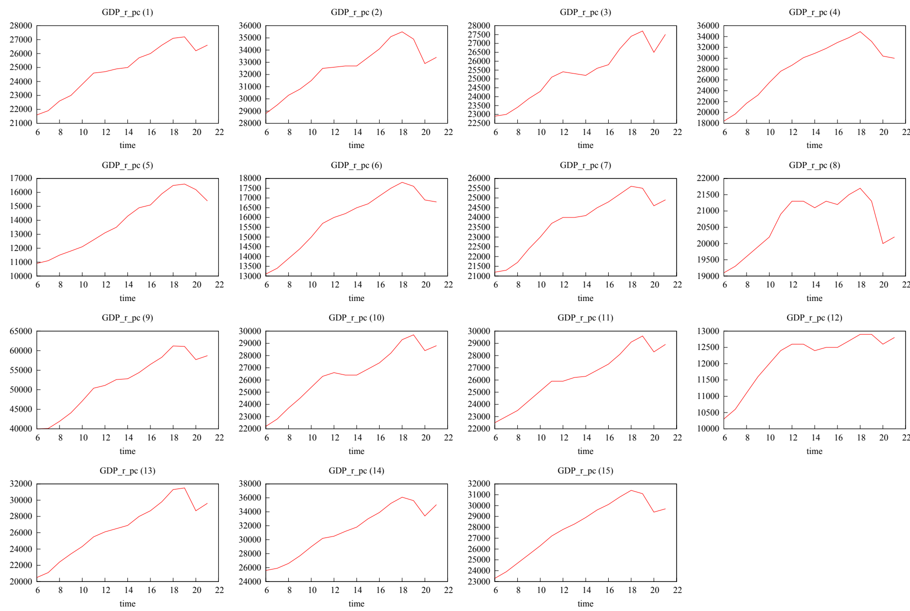

Figure A.2: Real GDP per capita, new member countries (EU-12), 1996-2010, EUR per inhabitant

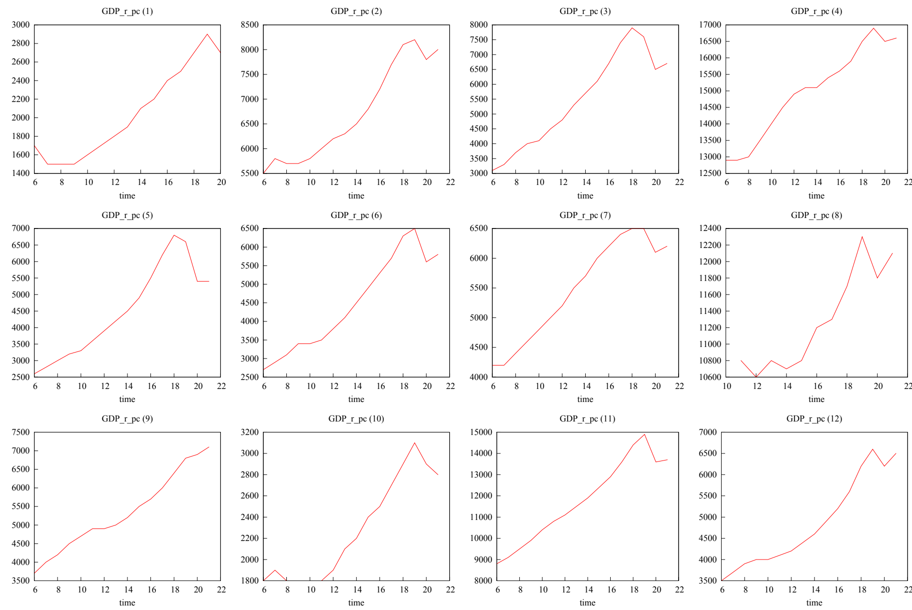

Figure A.3: Final energy consumption, total, original member countries (EU-15), 1990-2010, 1000 toe

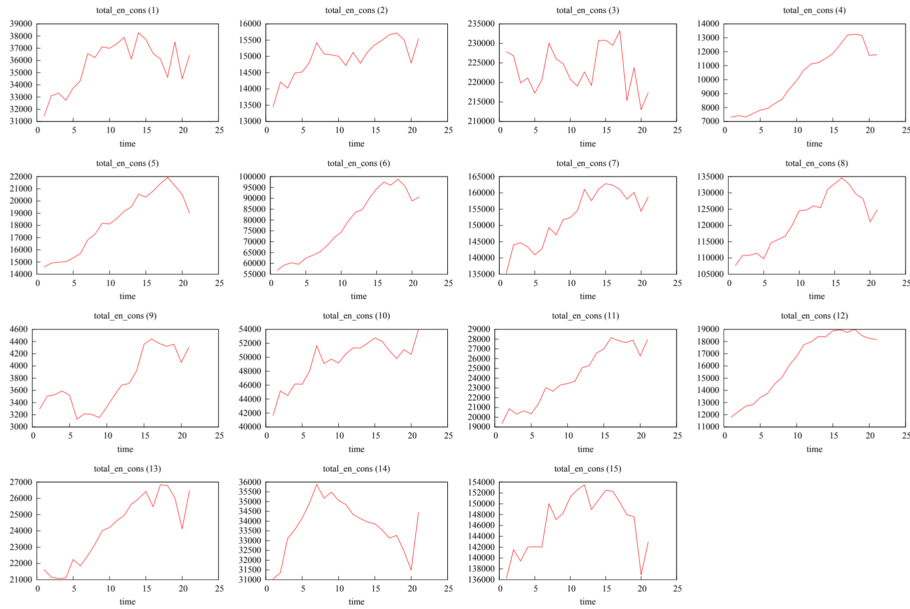

Figure A.4: Final energy consumption, total, new member countries (EU-12), 1990-2010, 1000 toe

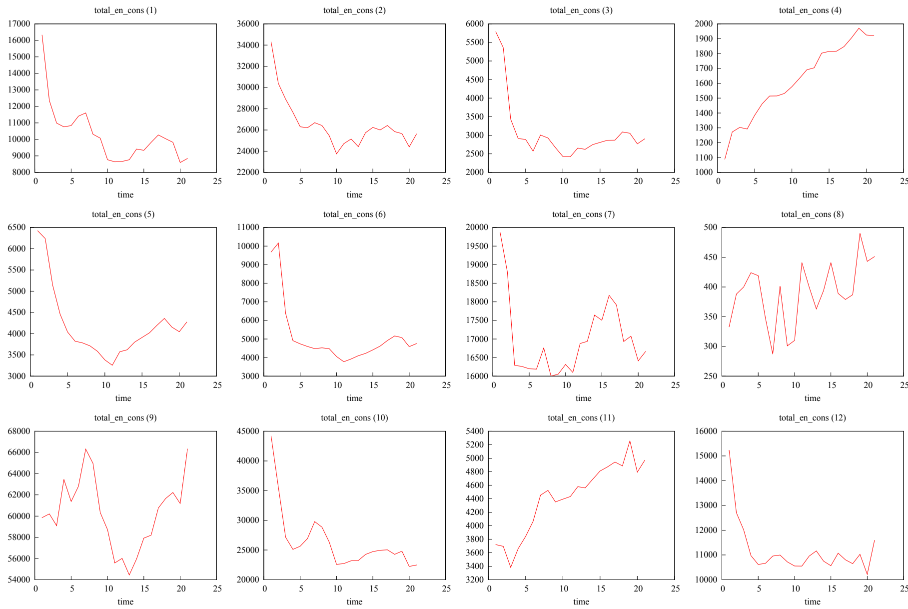

Table A.1: Country ordering in figures:

EU-27		EU-12		EU-15	
Belgium	1	Bulgaria	1	Belgium	1
Bulgaria	2	Czech Republic	2	Denmark	2
Czech Republic	3	Estonia	3	Germany	3
Denmark	4	Cyprus	4	Ireland	4
Germany	5	Latvia	5	Greece	5
Estonia	6	Lithuania	6	Spain	6
Ireland	7	Hungary	7	France	7
Greece	8	Malta	8	Italy	8
Spain	9	Poland	9	Luxembourg	9
France	10	Romania	10	Netherlands	10
Italy	11	Slovenia	11	Austria	11
Cyprus	12	Slovakia	12	Portugal	12
Latvia	13			Finland	13
Lithuania	14			Sweden	14
Luxembourg	15			United Kingdom	15
Hungary	16				
Malta	17				
Netherlands	18				
Austria	19				
Poland	20				
Portugal	21				
Romania	22				
Slovenia	23				
Slovakia	24				
Finland	25				
Sweden	26				
United Kingdom	27				