The effect of electricity consumption from renewable sources on countries' economic growth levels: Evidence from advanced, emerging and developing economies

Halkos, George and Tzeremes, Nickolaos

Department of Economics, University of Thessaly

14 October 2013

The effect of electricity consumption from renewable sources on countries' economic growth levels: Evidence from advanced, emerging and developing economies

George E. Halkos* **and Nickolaos G. Tzeremes**

Laboratory of Operations Research, Department of Economics,
University of Thessaly, Greece

Abstract
This paper uses a sample of 36 countries for the time period 1990-2011 in order to examine the relationship between countries' electricity consumption from renewable sources and Gross Domestic Product (GDP) levels. Several nonparametric techniques are applied to investigate the effect of electricity consumption from several renewable sources including wind, geothermal, solar, biomass and waste on countries' GDP levels. When investigating the whole sample ignoring countries' economic development status, the results reveal an increasing relationship up to a certain GDP level, which after that point the effect of electricity consumption on GDP stabilises. However when analysing separately the 'Emerging Markets and Developing Economies', and, the 'Advanced-Developed Economies', the results change significantly. For the case of Emerging Market and Developing Economies the relationship appears to be highly nonlinear (an M-shape form) indicating that on those countries the levels of electricity consumption from renewable sources will not result on higher GDP levels. In contrast for the case of the advanced economies the results reveal an increasing nonlinear relationship indicating that higher electricity consumption levels from renewable sources results to higher GDP levels. This finding is mainly attributed to the fact that in the advanced-developed economies more terawatts from renewable sources are generated and consumed compared to the emerging market and developing economies, which traditionally their economies rely on non-renewable sources for power generation and consumption.

Keywords: Renewable energy; Economic growth; Local linear estimator; Nonparametric analysis.

JEL Classifications: C14; Q40; Q01; Q20; C60; O44.

*Corresponding author: Professor George Halkos, Department of Economics, University of Thessaly, Korai 43, 38333, Volos, Greece. Tel.: 00302421074920. Fax: 00302421074772. *E-mail*: halkos@econ.uth.gr

1. Introduction

Since the pioneer work by Kraft and Kraft (1978) there has been a growing interest in the literature about the connection between energy consumption and economic growth. Mainly, there are four causal hypothesis regarding this causal relationship (Apergis and Payne 2010a). These are the *growth*, *conservation*, *feedback* and *neutrality hypotheses*[1]. More analytically, the *growth hypothesis* implies a unidirectional causality from energy consumption to economic growth. The *conservation hypothesis* describes a unidirectional causality from economic growth to energy consumption. The *feedback hypothesis* supports the bidirectional causality among energy consumption and economic growth. Finally, the *neutrality hypothesis* describes the case where energy consumption has no significant effect on economic growth and therefore energy conservation policies will not have a significant effect on economic growth.

However it must be mentioned that there is not a clear answer about which hypothesis is correct and the results across the literature are rather mixed failing to establish most of the time the same relationship following Granger causality tests (Soytas and Sari 2006, 2007). However this may be attributed to the fact that most of the studies use different country samples, for different time periods and from different developed stages (Yuan et al., 2008; Halkos and Tzeremes, 2009). Some other studies have focused on a similar manner their research in investigating the relationship between electricity consumption/generation and economic growth[2]. Again when comparing these studies the results provided investigating the causal relationship were mixed (Yoo 2006; Chen et al. 2007)[3].

---

[1]Ozturk (2010) presents a detailed review of the four hypotheses.
[2]Ghosh (2002, 2009) for the case of India, Altinay and Karagol (2005) for Turkey, Aqeel and Butt (2001) for Pakistan, Jumbe (2004) for Malawi, Shiu and Lam (2004) for China and Murry and Nan (1996) for East Asian countries.
[3]For an extensive literature review of studies investigating the causal relationship between electricity/energy use and economic growth see Lee (2005, 2006).

In contrast with the pre-mentioned studies, in this paper we provide empirical evidence for the *growth hypothesis* analyzing the effect of electricity consumption from renewable sources (RE) on countries' economic growth levels using the local linear estimator (Fan 1992; Fan and Gijbels 1996) without assuming any functional form of the examined relationship (Li and Racine 2007). The structure of the papers is the following. The next section presents the relative literature, whereas section 3 presents the data and the methods used. Section 4 presents the empirical findings from the nonparametric analysis, whereas the last section concludes the paper.

2. A brief literature on the energy consumption economic growth relationship

Ayres (2001) supports the feedback hypothesis and argues that primary resource flows (exergy), such as oil, are not just a result of economic growth but they are its principal factors. Mehrara (2007) investigates the connection between energy consumption and economic growth in oil exporting countries and finds evidence about the conservation hypothesis. Bowden and Payne (2010) analyze the causal relationship between energy consumption and economic growth using a Toda-Yamamoto approach. The authors use renewable and non-renewable energy consumption and as a growth measure they use GDP per sector and confirm the growth hypothesis for residential renewable energy sources (RES) consumption.

Additionally, the neutrality hypothesis explains the commercial and industrial consumption. Ozturk et al. (2010) apply a Pedroni (1999) panel cointegration approach, a panel causality test and the Pedroni (2001) method in order to investigate the causal relationship for 51 countries. The results indicate that energy consumption is cointegrated with GDP. Furthermore, the conservation hypothesis and the feedback hypothesis are confirmed for low and middle income countries respectively. Ozturk and Acaravci (2010a, b) apply an ARDL approach on five Eastern and Southeastern European countries. The authors study the causal relationship between energy consumption and GDP and they find evidence to support the neutrality hypothesis.

In an alternative study, Asafu-Adjaye (2000) argues that there are two contradictory approaches to examine the connection between energy consumption and economic growth. The first approach describes the energy as a limiting factor for economic growth while the second approach assumes a neutral relationship between them. Shi and Zhao (1999) confirm the connection among the rise of energy consumption in China and the slightly declined growth rates and Cropton and Wu (2005) validate their result. Rodriguez and Sachs (1999) argue that intensive-resource economies tend to experience lower growth rates than low-resource economies. Furthermore they explain this paradox with the temporally high growth rates of the intense-resource economy which are considerably above the steady state and they argue that the economy must converge back to its steady state. They demonstrate the case study of Venezuela, which is an oil exporter and an intense-resource country, in order to support the above assumption. Stinjs (2005) further supports the above findings. The author claims that a country rich in natural resources does not necessarily imply a country with high economic growth and they also find that the neutrality hypothesis is valid.

Mehrara (2007) presents four econometric approaches which according to the author are the most widely used in the literature in order to examine this connection. The first approach applies the conventional VAR methodology and assumes stationarity for the variables. The second approach relaxes the stationarity assumption and uses a Granger (1988) two-stage procedure for cointegration. The third approach employs the Johansen (1991) methodology, while the last approach applies panel cointegration and panel error correction models.

The popular concept of sustainable development does not conform with the highly dependence of the global economy on fossil fuels which are considered as one of the main reasons for global warming and climate change. The most widely used fossil fuels are oil, gas and coal and they produce various harmful gases such as CO_2 and SO_2. Moreover as we have already presented, the majority of the literature indicates a connection between energy and economic growth. If we combine this connection with the concept of sustainable development then we can understand that a more environmental-friendly path is needed which can be achieved by using sustainable energy sources.

Substituting fossil fuels with renewable energy sources (RES) will reduce the emissions and therefore the global pollution. The most important RES are solar, wind, geothermal, biomass, hydroelectricity, wave and tidal energy sources. Apergis and Payne (2010b) mark the significance of this substitution because of three reasons. First, the volatility of oil price might be a destabilizing economic factor. Awerbuch and Sauter (2006) also support this view. They investigate the connection between oil and economic growth and they find the significant effect of price volatility of oil on economic growth. Specifically, a 10% increase in oil price will result in 0.5% loss of the global GDP. This negative effect is contributed to inflation and unemployment.

The second reason of Apergis and Payne (2010b), is that non-renewable energy sources such as fossil fuels cause environmental degradation and contribute to global warming. Third, countries which use RES as their primary fuels are not depending on countries which are "energy-producers". Bowden and Payne (2010) propose a number of incentives for the promotion of RES which include tax credits and renewable energy standards.

Furthermore, international agreements are a significant contributor towards the substitution of fossil fuels with RES. One of the most important international agreements for the promotion of RES and the reduction of greenhouse gases is the Kyoto Protocol which was created through the United Nations Framework Convention on Climate Change (UNFCC). Another important agreement is the Renewable Energy Directive (2009/28/EC) of European Commission which sets objectives for the European Union members. These objectives include among others that the 20% of total energy and the 10% of transport energy to come from RES by 2020[4]. In addition, European country members are encouraged to set individual goals towards 2020.

So far we have presented studies about the relationship of energy and economic growth. It is interesting to examine specifically the relationship between RES and economic growth. Chien and Hu (2008) support the growth hypothesis. They apply Structural Equation Modeling at 116 countries and they examine the relationship between RES and GDP. They decompose GDP and find that RES promotes growth through capital formation but not through trade balance. The conservation hypothesis is supported by Sadorsky (2009a) who applies a panel cointegration approach to study the RES consumption in G7 countries. The findings reveal that GDP per capita has a significant effect on RES consumption. Sadorsky (2009b) finds similar results for 18 developing economies during the period 1994-2003. In particular, the author applies a panel cointegration and a vector error correction model and validates that per capita GDP has a significant positive influence on RES consumption.

Apergis and Payne (2010a) investigate 13 Eurasian countries during the period 1992-2007 using a multivariate panel model. They confirm the feedback hypothesis both in short and long run. Apergis and Payne (2010b) and Apergis and Payne (2012) in similar studies about 20 OECD countries and 80 countries respectively, also validate the feedback hypothesis. Tugcu et al. (2012) apply an ARDL approach to investigate the relationship

[4] http://www.seai.ie/Publications/Statistics_Publications/Statistics_FAQ/Energy_Targets_FAQ/

between RES and non-RES consumption and economic growth for G7 countries. The results confirm the feedback hypothesis for both RES and non-RES consumption. Pao and Fu (2013) investigate the connection between various energy sources including RES and economic growth in Brazil. In all cases they find evidence about the feedback hypothesis. Menegaki (2011) applies a random effects model to investigate the case of 27 European countries to examine the relationship between RES consumption and GDP and finds evidence about the neutrality hypothesis. Yildirim et al. (2012) also support the neutrality hypothesis in a study about RES in USA.

Interesting insights are provided by Chang et al. (2009) who investigate the relationship of energy prices and under different levels of economic growth in OECD countries during the period 1997-2006. The authors apply a panel threshold regression model and they find that on the one hand countries with higher growth rates tend to increase RES consumption when energy prices increase, thus supporting the conservation hypothesis.

On the other hand, countries with lower growth rates do not respond to energy prices volatility which supports the neutrality hypothesis. Ocal and Aslan (2013) investigate the relationship among RES and economic growth in Turkey. The authors apply an ARDL methodology and Toda-Yamamoto causality tests. The results from ARLD methodology reveal a negative effect of RES on economic growth. The results from the causality tests show support conservation hypothesis because economic growth seems to affect RES consumption.

3. Data and Methodology

In order to examine the relationship between electricity consumption from renewable sources and economic growth, we use a sample of 36 advanced/developed and emerging market/developing economies[5] for the time period of 1990-2011. Table 1 presents diachronically the descriptive statistics of the variables used. As dependent variable real GDP at chained PPPs (in mil. 2005 US $) is used.[6] Our explanatory variable is the renewable energy (RE) derived from electricity consumption generated from renewable sources including wind, geothermal, solar, biomass and waste, and not accounting for cross border electricity supply[7].

Table 1: Descriptive statistics of the variables used

Real GDP at chained PPPs (in mil. 2005US$)											
Year	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Mean	853297	872121.1	879003.5	909376.8	945368.3	988341	1021978	1055837	1068948	1105954	1164976
Std	1432173	1442635	1465812	1516400	1578806	1633468	1691574	1762027	1822407	1906348	1991311
Min	59045.98	59620.46	63567.6	66246.9	70053.45	77840.9	79206.96	81718.01	83765.89	89037.73	92620.03
Max	7963012	7925630	8211395	8469315	8842204	9071050	9430334	9869378	10309118	10807267	11275426
Year	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*
Mean	1185841	1211300	1246252	1306651	1378219	1428579	1500818	1539125	1539425	1596276	1648284
Std	2019557	2066191	2135077	2231294	2327630	2382874	2498548	2564076	2602210	2633978	2748542
Min	95492.48	98469.09	100061.9	98991.92	101895	101978.8	104614.9	100917.8	105678.4	105612.3	103125.7
Max	11368939	11515518	11789128	12196382	12564300	12564300	12898268	13149344	13066677	12597854	13193478
Electricity consumption from renewable sources measured in Terawatt-hours											
Year	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Mean	3.230311	3.408462	3.636372	3.79314	3.974314	4.130339	4.342958	4.659052	4.980527	5.406078	5.798083
Std	10.36327	10.99121	11.72366	12.09705	12.14691	11.65342	11.96016	12.20117	12.16285	12.55611	12.78047
Min	0.065	0.065	0.063	0.06	0.061	0.059	0.057	0.057	0.058	0.058	0.0809
Max	63.75396	67.67951	72.31031	74.72371	74.81041	71.74429	73.51897	74.74439	74.44078	76.8001	78.15092
Year	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*
Mean	6.05037	6.837621	7.415457	8.448851	9.472582	10.57258	12.05043	13.77112	15.79444	18.62163	21.95844
Std	12.23443	13.76689	14.1046	15.06694	16.20486	18.03482	20.32977	23.57836	26.54562	30.96045	36.7259
Min	0.1171	0.131	0.131	0.2549	0.2758	0.3745	0.4908	0.4938	0.4919	0.492203	0.493381
Max	74.18368	82.80884	83.17178	86.81329	91.14479	100.4533	109.2851	130.3464	148.6917	171.8944	200.0856

[5]**Advanced-developed countries (23)**: Australia, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Japan, Korea Republic of, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Taiwan, United Kingdom and the United States of America. **Emerging market-developing countries (13)**: Argentina, Brazil, Chile, China, Colombia, Hungary, India, Indonesia, Mexico, Philippines, Poland, Russia, Turkey (IMF Advanced Economies List, 2012, p.179-183).

[6]GDP has been extracted from Penn World Table-PWT 8.0 (Feenstra et al., 2013).

[7]The data has been extracted from the Statistical Review of World Energy and are available from: http://www.bp.com/

As dependent variable real GDP at chained PPPs (in mil. 2005 US $) is used.[8] Our explanatory variable is the renewable energy (RE) derived from electricity consumption generated from renewable sources including wind, geothermal, solar, biomass and waste, and not accounting for cross border electricity supply[9].

Since we cannot assume a specific functional form for the examined relationship we apply nonparametric techniques which are not restrictive to any functional forms. Let the dependent variable (GDP) be denoted by y_i and let the independent variable X_i represents the energy consumption derived from renewable sources. We assume that the examined variables are continuous with a joint density $f(y,x)$, having a marginal density of X_i which can be defined as $f(x)=\int f(y,x)dy$. In this way the conditional density of y_i given X_i can be defined as $f(y|x)=f(y,x)/f(x)$. Then in a nonparametric setting the following regression function will take the form:

$$g(x)=E(y_i|X_i=x) \quad (2).$$

Following Li and Racine (2007, Theorem 2.1, p. 59) the regression function can be written as:

$$g(x)=\frac{\int yf(y,x)dy}{f(x)} \quad (3),$$ thus

we can estimate g by replacing the density functions by their nonparametric estimates. Therefore the estimate of the joint density can be computed nonparametrically as:

$$\hat{f}(y,x)=\frac{1}{n|H|h_y}\sum_{i=1}^{n}K\left(H^{-1}(X_i-x)\right)k\left(\frac{y_i-y}{h_y}\right) \quad (4).$$

Where h_y is a bandwidth for smoothing in the y direction, whereas $H=diag(h_1,...,h_q)$.

[8]GDP has been extracted from Penn World Table-PWT 8.0 (Feenstra et al., 2013).
[9]The data has been extracted from the Statistical Review of World Energy and are available from: http://www.bp.com/

In addition $K(.)$ is a product kernel function and $k(.)$is a univariate kernel function that satisfies the following conditions:

$$\int k(u)du = 1, \;\; k(u) = k(-u), \;\; \int u^2 k(u)du = \kappa_2 > 0 \qquad (5).$$

In equation (5) $k(u) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2}, -\infty < u < \infty$ denotes the Gausian kernel (see for details Li and Racine, 2007, p. 8-11). Moreover, the nonparametric estimate of marginal density of X_i can be defined as:

$$\begin{aligned} \hat{f}(x) = \int \hat{f}(y,x) &= \frac{1}{n|H|h_y} \sum_{i=1}^{n} K\left(H^{-1}(X_i - x)\right) \int k\left(\frac{y_i - y}{h_y}\right) dy = \\ &= \frac{1}{n|H|} \sum_{i=1}^{n} K\left(H^{-1}(X_i - x)\right) \end{aligned} \qquad (6), \text{ and}$$

$$\begin{aligned} \int y \hat{f}(y,x)dy &= \frac{1}{n|H|h_y} \sum_{i=1}^{n} K\left(H^{-1}(X_i - x)\right) \int yk\left(\frac{y_i - y}{h_y}\right) dy \\ &= \frac{1}{n|H|} \sum_{i=1}^{n} K\left(H^{-1}(X_i - x)\right) y_i \end{aligned} \qquad (7).$$

Finally, the local linear estimator (Fan 1992; Fan and Gijbels 1996) can be obtained as:

$$\min_{\{a,b\}} \sum_{j \neq 1, j=1}^{n} \left[Y_j - a - (X_j - X_i)' b \right]^2 K\left(\frac{X_j - X_i}{h}\right) \qquad (8).$$

where $K\left(\frac{X_j - X_i}{h}\right) = \prod_{s=1}^{q} k\left(\frac{X_{is} - X_{js}}{h_s}\right)$. Then let $\hat{g}_{-i,L}(X_i)$ denote the leave-one-out linear estimator of $g(X_i)$ and $\left(\hat{a}_i, \hat{b}_i\right)$ be the solution of (a,b), then $\hat{a}_i \equiv \hat{g}_{-i,L}(X_i)$.

Following Li and Racine (2007, p. 83) the local linear least squares cross-validation approach is introduced by choosing $h_1,...,h_q$ to minimize the objective:

$$CV_{ll}\left(h_1,...,h_q\right)=\min_h n^{-1}\sum_{i=1}^{n}\left(Y_i-\hat{g}_{-i,L}\left(X_i\right)\right)^2 M\left(X_i\right) \quad (9),$$

where $\hat{g}_{-i}(X_i)=\sum_{l\neq i}^{n} y_l\left(K(X_i-X_l)/h\right)/\sum_{l\neq i}^{n}\left(K(X_i-X_l)/h\right)$, which is the leave–one-out kernel estimator of $g(X_i)$ and $0\leq M(.)\leq 1$ is a weight function.

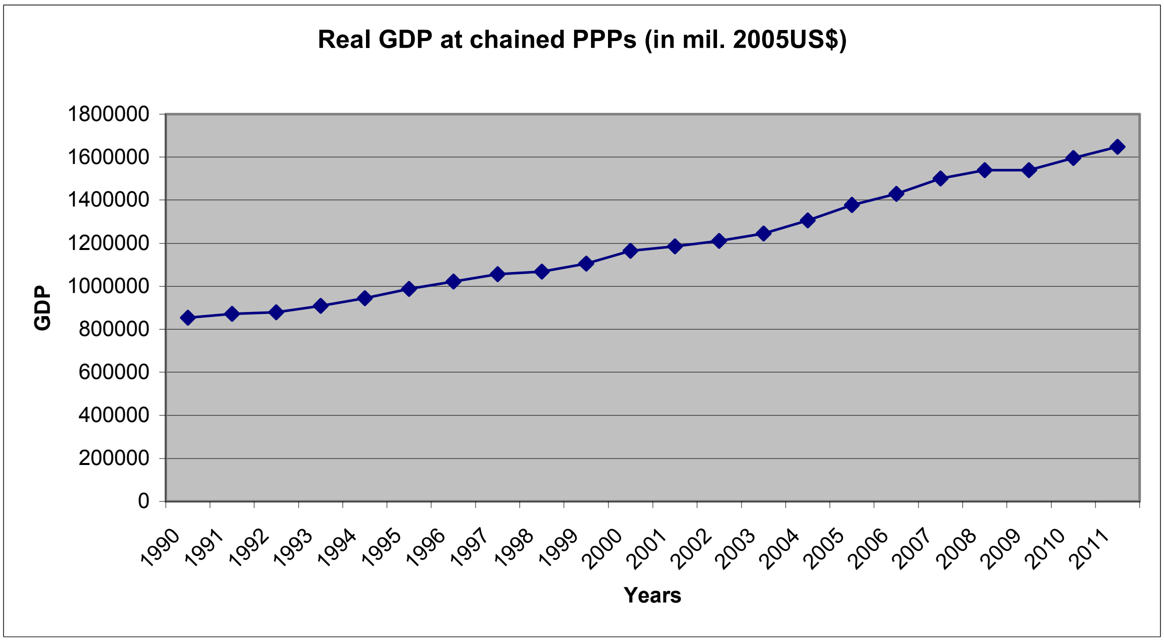
4. Empirical results

Looking at the diachronical representation of the variables used (Figure 1) we can see an increasing trend for countries' GDP levels (subfigure 1a) and for electricity consumption from renewable sources (subfigure 1b). More analytically, advanced and developed countries appear to consume diachronically more levels of electricity derived from renewable sources compared to the emerging market and developing countries.

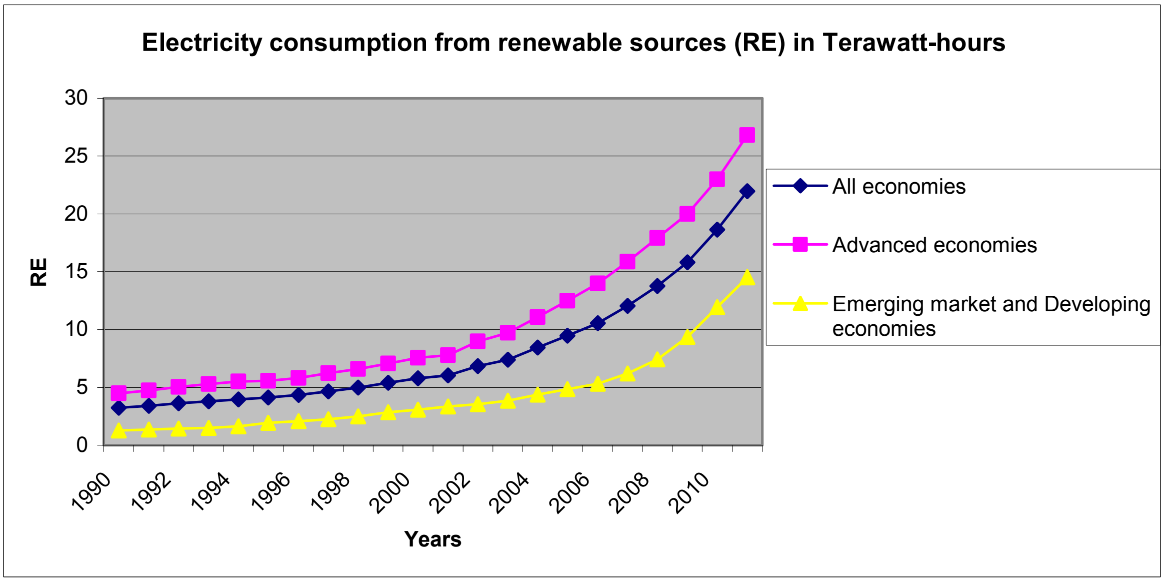
Following the bootstrap algorithms introduced by Racine (1997), Racine et al. (2006) and Racine (2008) we test the significance of the independent variable (RE). Table 2 presents the obtained *p-values* of the nonparametric significance test alongside with the selected bandwidths following the local linear (ll) least squares cross-validation approach introduced by Li and Racine (2007). The results reveal that the electricity consumption from renewable sources (RE) is statistical significant for all the examined cases explaining countries' growth variation. Moreover, the obtained R-squared values signify that the RE variable explains 54% for the advanced and developed countries' economic growth variations in contrast with the emerging market and developing countries which explains only the 20% of their economic growth variations. This finding suggests that developing countries find their comparative advantage shifting to higher polluting production sectors using conventional energy sources (Pellegrini, 2011).

Figure 2 presents schematically the relationship between electricity consumption from renewable sources and countries' GDP levels alongside with asymptotic error bounds. When the full sample (subfigures 2a, 2b) is examined the nonparametric regression line indicates an increasing trend between RE and countries GDP levels. Moreover a similar picture appears in the case of advanced/developed economies. More analytically subfigure 2c presents also the time effect in contrast with subfigure 2d which presents only the effect of electricity energy consumption from renewable sources on countries' GDP levels. The results reveal that the effect of time (Year) has a posit ive effect on countries' GDP levels alongside with RE.

Figure 1: Diachronical representation of the variables



1a



1b

Table 2: Results from the local linear nonparametric regression

Model summary			
	Bandwidth	p-value	R-squared
RE (All economies)	34.01587	0.0254**	0.4036
RE (Advanced economies)	31.82791	0.0000***	0.5460
RE (Emerging Market and Developing economies)	19.07234	0.0411**	0.2022

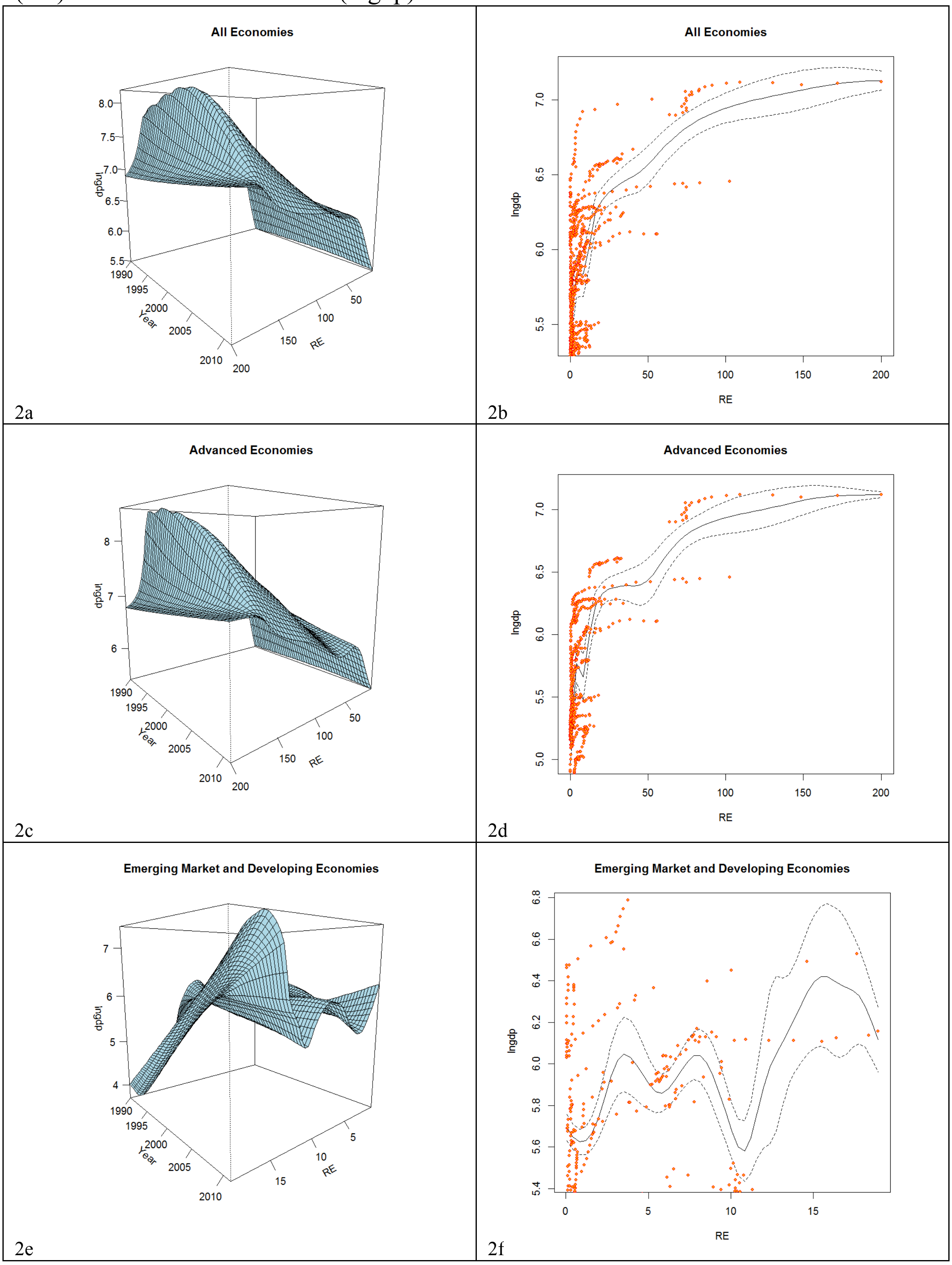
10%, ** 5%, * 1% significance level*

When examining only the effect of RE on advanced economies' GDP levels it appears that the effect is highly positive in a nonlinear manner indicating that for advanced economies electricity consumption from renewable sources can be a source of economic growth. However we cannot conclude the same in the case of emerging market/developing economies (subfigure 2e, 2f). As reported in subfigure 2e the effect of time is highly positive for developing countries' GDP levels. Moreover it can be said that is more positive to their economic growth levels compared to the developed economies. This is indicated from the highly increasing trend.

However it cannot be justified the same for the RE variable. In fact looking at subfigure 2f a nonlinear relationship can be observed indicated by an 'M' shape up to a consumption level of 10 terawatts per hour. After that consumption level the trend is increasing and then decreasing again forming an inverted 'U' shape. Several authors suggest that this phenomenon is attributed to the inefficient electrification programs using RE for those countries (Haanyika 2006; Urmee et al. 2009).

Moreover, other reasons may be attributed to high cost of transmission and distribution, institutional weaknesses and inappropriate policy framework (Urmee et al., 2009). Finally, Beck and Marinot (2004) suggest that the barriers and lack of implementation of renewable sources in emerging market and developing countries is mainly attributed to a) costs and pricing issues, b) legal and regulatory policies and c) market performance factors. More analytically they suggest that barriers related to cost and pricing involve subsidies for competing fuels, high initial capital costs, difficulty of fuel price risk assessment, unfavourable power pricing rules, transaction costs and environmental externalities

Figure 2: Graphical representation of the effect of renewable electricity consumption (RE) on countries' GDP levels (lngdp)



In addition, barriers to renewable sources related to legal and regulatory aspects include issues related to the lack of legal framework for independent power producers, restriction on sitting and construction, transmission access, utility interconnection requirements and liability insurance requirements. Finally according to Beck and Marinot (2004) barriers related to market performance include lack of access to credit, uncertainty and risk related to perceived technology performance and lack of technical or commercial skills and information.

5. Conclusions

This paper analyses the effect of electricity consumption from renewable sources on countries' economic growth. Based on the *growth hypothesis* our paper applies a local linear estimator in order to analyze the examined relationship both for a sample of advanced/developed and emerging market/developing countries for the period 1990-2011.

The empirical findings reveal a positive relationship for the sample of advanced economies indicating that electricity consumption from renewable sources is a vital contributor to economic growth. However for the developing economies the relationship is nonlinear indicated by an 'M' shape relationship up to a consumption level of 10 terawatts per hour.

However for higher consumption values of 10 TWh the relationship forms an inverted 'U' shape relationship. Mainly this phenomenon is attributed to barriers and lack of implementation of renewable sources based on costs and pricing issues, legal and regulatory policies and market performance factors.

Acknowledgements

An earlier draft of this study was presented in the 6th International Scientific Conference on “Energy and Climate Change”, 9-11 October 2013 organized by the Energy Policy and Development Centre (KEPA) of the National and Kapodistrian University of Athens. We thank the participants for the comments and discussion. Any remaining errors are solely the author’s responsibility.

References

Altinay G., Karagol E. (2005). Electricity consumption and economic growth: Evidence from Turkey. *Energy Economics*, 27, 849-856.

Apergis N., Payne J.E. 2010a. Renewable energy consumption and growth in Eurasia. *Energy Economics*, 32, 1392-1397.

Apergis N., Payne J.E. 2010b. Renewable energy consumption and economic growth: Evedence from a panel of OECD countries. *Energy Policy*, 38, 656-660.

Apergis N., Payne J.E. 2012. Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. *Energy Economics*, 34, 733-738.

Aqeel A., Butt M.S. (2001). The relationship between energy consumption and economic growth in Pakistan. *Asia-Pacific Development Journal*, 8, 101-109.

Asafu-Adjaye J. (2000). The relationship between energy consumption, energy prices and economic growth, *Energy Economics*, 22, 615-625.

Awerbuch S. and Sauter R. 2006. Exploiting the oil-GDP effect to support renewables deployment. *Energy Policy*, 34, 2805-2819.

Ayres R. (2001). The minimum complexity of endogenous growth models: the role of physical resource flows, *Energy*, 26, 817-838.

Beck F, Marinot E. (2004). Renewable energy policy and barriers. *Encyclopedia of Energy*, 5, 365-383.

Bowden N, Payne J.E. (2010). Sectoral analysis of the causal relationship between renewable and non-renewable energy consumption and real output in the US. *Energy Sources, Part B: Economics, Planning and Policy*, 5(4), 400-408.

Chang T.H., Huang C.M., Lee M.C. (2009). Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: Evidence from OECD countries. *Energy Policy*, 37, 5796-5802.

Chen ST, Kuo HI, Chen C.C. (2007). The relationship between GDP and electricity consumption in 10 Asian countries. *Energy Policy*, 35, 2611-2621.

Chien T., Hu J.L. (2008). Renewable energy: An efficient mechanism to improve GDP. *Energy Policy*, 36, 3045-3052.

Crompton P., Wu Y. (2005). Energy consumption in China: past trends and future directions, *Energy Economics*, 27, 195-208.

Fan, J. (1992). Design-adaptive nonparametric regression, *Journal of the American Statistical Association*, 87, 998–1004.

Fan, J., Gijbels, I. (1996). *Local Polynomial Modelling and its Applications*. London: Chapman and Hall.

Feenstra R.C., Inklaar R., Timmer M.P. (2013). The next generation of the Penn World Table. Available from: www.ggdc.net/pwt.

Ghosh S. (2002). Electricity consumption and economic growth in India. *Energy Policy*, 30, 125-129.

Ghosh S. (2009). Electricity supply, employment and real GDP in India: Evidence from cointegration and Granger-causality tests. *Energy Policy*, 37, 2926-2929.

Granger C.W.J. (1988). Causality, cointegration and control. *Journal of Economic Dynamics and Control*, 12, 551-559.

Haanyika CM. (2006). Rural electrification policy and institutional linkages. *Energy Policy*, 34,2977–93.

Halkos G.E., Tzeremes N.G. (2009). Electricity generation and economic efficiency: panel data evidence from World and East Asian Countries. *Global Economic Review*, 38, 251-263.

IMF Advanced Economies List, (2012). World Economic Outlook, April, 179-183.

Johansen S. (1991). Estimation and hypothesis-testing of cointegration vectors in gaussian vector autoregressive models. *Econometrica*, 59 (6), 1551-1580.

Jumbe C. B. L. (2004). Cointegration and causality between electricity consumption and GDP: Empirical evidence from Malawi. *Energy Economics*, 26, 61-68.

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

Lee C.C. (2005). Energy consumption and GDP in developing countries: A cointegrated panel analysis. *Energy Economics*, 27, 415-427.

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

Li Q., Racine J.S. (2007). Nonparametric econometrics: Theory and practice, Princeton University Press, Oxford.
Mehrara M. (2007). Energy consumption and economic growth, *Energy Policy*, 35, 2939-2945.

Menegaki A.N. (2011). Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. *Energy Economics*, 33, 257-263.

Murry D.A., Nan G.D. (1996). A definition of the gross domestic product_electrification interrelationship. *The Journal of Energy and Development*, 19, 275-283.

Ocal O., Aslan A. (2013). Renewable energy consumption-economic growth nexus in Turkey. *Renewable and Sustainable Energy Reviews*, 28, 494-499.

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

Ozturk I., Acaravci A. (2010a). The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary and Romania: Evidence from ARDL bound testing approach. *Applied Energy*, 87, 1938-1943.

Ozturk I., Acaravci A. (2010b). CO2 emissions, energy consumption and economic growth in Turkey. *Renewable and Sustainable Energy Reviews*, 14, 3220-3225.

Ozturk I., Aslan A., Kalyoncu H. (2010). Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries. *Energy Policy*, 38, 4422-4428.

Pao H-T, Fu H-C. (2013). The causal relationship between energy resources and economic growth in Brazil. *Energy Policy*, 61, 793-801.

Pedroni P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics*, 61, 653-678.

Pedroni P. (2001). Purchasing power parity tests in cointegrated panels. *The Review of Economics and Statistics*, 83, 727-731.

Pellegrini, L., (2011). Corruption, development and the environment. Springer Science and Business Media B.V., Springer.

Racine, J.S., (1997). Consistent significance testing for nonparametric regression. *Journal of Business Economics and Statistics* 15, 369–379.

Racine, J.S., Hart, J.D., Li, Q., (2006). Testing the significance of categorical predictor variables in nonparametric regression models. *Econometric Reviews* 25, 523–544.

Racine, J.S., (2008). Nonparametric Econometrics: A Primer. *Foundation and Trends in Econometrics* 3, 1-88.

Rodriguez F., Sachs J. (1999). Why do resource abundant economies grow more slowly? *Journal of Economic Growth*, 4 (3), 277-303.

Sadorsky P. (2009a). Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. *Energy Economics*, 31, 456-462.

Sadorsky P. (2009b). Renewable energy consumption and income in emerging economies. *Energy Policy*, 37, 4021-4028.

Shi, Q., Zhao J. (1999). Development Report of Chinese Industries. China ZhiGong Publishing House, eds, Beijing.

Shiu A., Lam P. L. (2004) Electricity consumption and economic growth in China. *Energy Policy*, 32, 47-54.

Soytas U., Sari R. (2006). Can China contribute more to the fight against global warming? *Journal of Policy Modeling*, 28, 837-846.

Soytas U., Sari R. (2007). The relationship between energy and production: Evidence from Turkish manufacturing industry. *Energy Economics*, 29,1151-1165.

Stinjs J.P.C. (2005). Natural resource abundance and economic growth revisited, *Resources Policy*, 30, 107-103.

Tugcu C.T., Ozturk I., Aslan A. (2012). Renewable and non-renewable energy consumption and economic growth relationship: Evidence from G7 countries. *Energy Economics*, 34, 1942-1950.

Urmee,T., Harries, D., Schlapfer, A. (2009). Issues related to rural electrification using renewable energy in developing countries of Asia and Pacific. *Renewable Energy*, 34, 354-357.

Yildirim E., Sarac S., Aslan A. (2012). Energy consumption and economic growth in the USA: Evidence from renewable energy. *Renewable and Sustainable Energy Reviews*, 16, 6770-6774.

Yoo S.H. (2006). The causal relationship between electricity consumption and economic growth in the ASEAN countries. *Energy Policy*, 34, 3573-3582.

Yuan J. H., Kang J. G., Zhao C. H., Hu Z. G. (2008). Energy consumption and economic growth: Evidence from China at both aggregated and disaggregated levels. *Energy Economics*, 30, 3077-3094.