Environmental Engineering and Management Journal

Novemver 2015, Vol.13, No. 11, 2825-2830
http://omicron.ch.tuiasi.ro/EEMJ/

"Gheorghe Asachi" Technical University of Iasi, Romania

RENEWABLE ENERGY CONSUMPTION, R&D AND GDP IN EUROPEAN UNION COUNTRIES

Imre Kocsis*, Judit T. Kiss

University of Debrecen Faculty of Engineering, Ótemető 2-4, 4028 Debrecen, Hungary

Abstract

The relationship between the use of renewable energy sources and other characteristics of national economies has frequently been investigated, and a wide range of approaches can be observed in publications. The aim of this study to examine the potential relationship between the ratio of renewable consumption in gross energy consumption, GDP per capita, and R&D expenditures in European Union countries. Data are analyzed in their original forms, and a mathematical model is presented that is suitable to analyze the effect of change in the input data further. A positive relationship is determined between R&D expenditure and renewable energy consumption at various levels of GDP. The results indicate that the impact of GDP is positive at a higher level of R&D expenditure, but the effect is not unambiguous at a lower level of R&D expenditure.

Key words: GDP, R&D expenditure, renewable energy consumption, support vector regression

Received: February, 2014; Revised final: October, 2014; Accepted: October, 2014

1. Introduction

The relationships between GDP and energy consumption (EC) and between GDP and renewable energy consumption (REC) have been examined in several studies (Guillet, 2010; Kum et al., 2012; Ohler and Fetters, 2014; Payne, 2010; Vaona, 2012; Wang et al., 2011). However, the results of these studies and empirical evidence are mixed, as we can find unidirectional causality (Payne, 2010; Wang et al., 2011), bidirectional causality (Soytas and Sary, 2003 – in the case of Argentina, Kum et al., 2012), and no causality (Akkemik and Göksal, 2012). Four different and competing hypotheses have been identified on the basis of the relationship between GDP and energy consumption in the literature on energy economics (Fallahi, 2011).

The growth hypothesis states that causality runs from EC to GDP, which means that reduction of EC decreases GDP. According to the conservation hypothesis, there is causality from GDP to EC; therefore, reduction of energy consumption due to an energy conservation policy will not have a negative effect on GDP. There is no causal relationship between EC and GDP under the neutrality hypothesis. In accordance with the feedback hypothesis, there is bidirectional causality between EC and GDP. An increase in energy consumption would increase GDP.

We can also find studies in the literature on energy economics that examine the relationship between (renewable) energy consumption, expenditures on R&D, and an economy's output (Ohler, 2014; Vaona, 2012; Wong et al., 2013). Payne (2011) analyzed the relationship between GDP and biomass consumption in U.S. for the period 1949-2007 and found a positive unidirectional relationship between the two mentioned variables. Similarly, Ohler and Fetters (2014) also examined the relationship between biomass consumption (BC) and GDP and showed a short-run bidirectional relationship between BC and GDP. They found short-run bidirectional causality between real GDP and renewable energy. Their findings therefore

* Author to whom all correspondence should be addressed: E-mail: kocsisi@eng.unideb.hu; Phone: 003652415155; Fax: 003652418643

provided support for the feedback hypothesis between renewable energy and real GDP. Ohler and Fetters (2014) established that individual sources of renewable energy differ in their impact on economic growth as well as in their environmental impact.

Consequently, economic conservation policies may have a negative impact on GDP. According to a study for OECD countries with oil reserves and without such reserves, energy R&D is an important factor driving economic growth (Wong et al., 2013). Wong et al. (2013) showed that renewable energy consumption has a sizeable and significant impact on economic growth, specifically in countries without oil reserves.

In this paper, we examine the relationship between renewable energy consumption, expenditures on R&D, and the amount of GDP using the support vector regression model for European Union countries between 2004 and 2012.

2. Data description

Support for the use of renewable energy can contribute to sustainable development in the long term, result in reduced energy dependency, and improve competition in the energy market. Furthermore, a reliable, efficient, safe, and affordable energy supply is vital in terms of a country's energy policy. The share of renewable energy in gross final energy consumption increased in the European Union countries as shown in Fig. 1. This may indicate an increasing awareness of the significance of environmental protection and a safe energy supply. The European Union average rose by 5.8 percentage points (Fig. 1), with the largest change occurring in Sweden, Denmark, Austria, and Italy (12.3, 11.5, 9.4, and 7.8 percentage points, respectively (Fig. 1). The ratio of renewable energy consumption to gross final energy consumption is lower than the average for most European Union countries.

Total expenditures on R&D as a percentage of GDP increased in European countries with the exception of Croatia and Sweden (Fig. 2). The European Union average rose by 0.24 percentage points. Slovenia and Estonia saw the first and the second greatest increases in R&D expenditures as a percentage of GDP, respectively (Fig. 2).

Fig. 3 shows that GDP per capita increased in the European Union, especially in Estonia, Lithuania, Poland, and Slovenia where the increase was 76%, 75%, 69%, and 65%, respectively. Half of European Union member countries experienced an increase below the EU's average rate of increase.

A debate in the literature on energy economics concerns whether renewable energy consumption and R&D expenditures contribute to GDP growth. In this study, we analyze the role that GDP and R&D expenditures play in changing renewable energy consumption. The previously examined data of European Union countries on the share of renewable energy consumption in gross energy consumption, R&D expenditures as a percentage of GDP and GDP per capita based on purchasing power parity are taken into account in the analysis for the period 2004-2012.

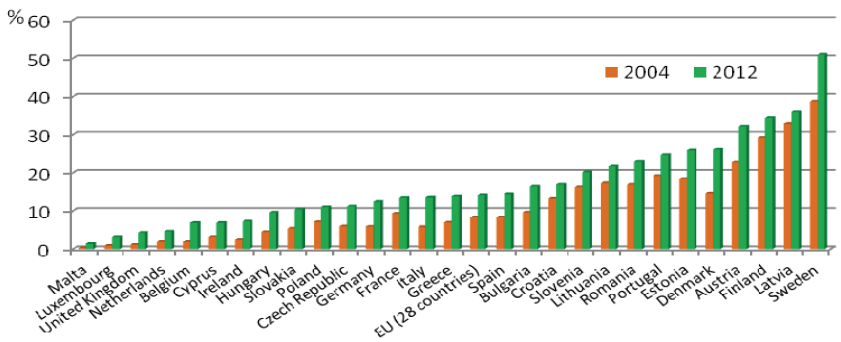

Fig. 1. Share of renewable energy in gross final energy consumption (%) (Eurostat, 2014a)

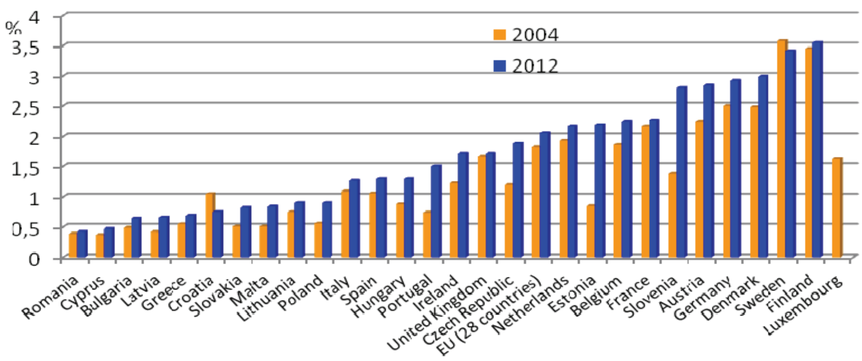

Fig. 2. Total R&D expenditures as a percentage of GDP (%) (Eurostat, 2014b)

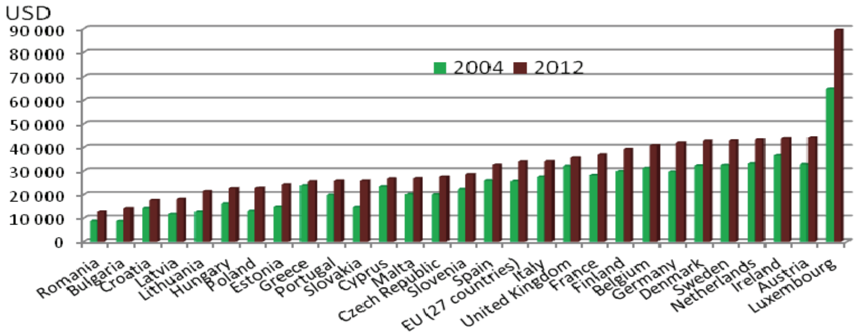

Fig. 3. Gross domestic product per capita based on purchasing power parity (USD) (HCSO, 2014)

3. The regression model

Methods belonging to the area of support vector machines (SVM) have seen frequent use recently, including in many fields of engineering sciences and economics, among others. The flexibility and efficiency of SVM have been proven in solving very different problems that can be traced back to pattern classification or nonlinear regression tasks. One of the model's strengths is the special concept for error (the roots of this approach go back to the statistical learning theory). The variety of functions that can be used as kernel functions makes this tool suitable in a wide range of examinations.

In our calculations, the support vector regression (SVR) model was chosen to solve the two-variable nonlinear regression problem. This model is chosen in many cases when the connection between the output and input parameters of a complex system is sought when there is a lack of information about the class to which the connection function belongs. Calculations were carried out in the framework of the open-source statistical software R using an E1071 package prepared for SVR applications (R Core Team, 2013; Meyer et al., 2014).

Several kernel functions were tested in the investigation (e.g., the most frequently used Gauss kernel function from the class of radial basis kernel functions). The polynomial Kernel function (Eq. 1):

$$K(\bar{x},\bar{x}_i) = \left(a \cdot \bar{x} \cdot \bar{x}_i + c_0\right)^d \tag{1}$$

(with three parameters: a, c_0, and d) proved to be the most accurate for our data. In the calculation, two further user-specified parameters (so-called hyper-parameters) are to be considered: the first one is ε belonging to the error function (the so-called ε-insensitive loss function that was originally defined by Cortes and Vapnik (1995) The second is C, generally called penalty parameter, which controls the role of so-called slack variables (Haykin, 2009). Hyper-parameters were determined using a grid search and n-fold cross-validation.

The connection between the output parameter (share of renewable energy in gross final energy consumption) and the two input parameters (GDP per capita and the rate of R&D expenditures in GDP) was calculated using Eq. (2):

$$y(\bar{z}) = \sum_{i=1}^{n}\left(\alpha_i - \alpha_i'\right) \cdot K\left(\bar{z},\bar{x}_i\right) + b \tag{2}$$

where: the number of indices i for which $\alpha_i \neq 0, \alpha_i' \neq 0$ is given by the number of so-called support vectors. Vector $\bar{x}$ symbolizes the input data and y is for the output value.

4. Analysis of the relationship between R&D Expenditures, GDP and renewable energy consumption using the regression model

The SVR method was applied to estimate the connection between GDP per capita, R&D expenditures (as input data) and the share of renewable energy consumption (as output value). The distribution of (GDP per capita-R&D expenditures) pairs can be seen in Fig. 4. The shape of the distribution suggests that regression could provide a sufficiently accurate result in two regions, which was confirmed by the calculations. Considering the values of GDP per capita,, the USD 16,000-30,000 and the USD 30,000-45.000 intervals were chosen for support vector regression (Fig. 4).

Fig. 5 shows the shape of the surface obtained from SVR for input data where the value of GDP per capita is between USD 30,000 and USD 45,000. In the calculation, 85 learning points and 7 test points were used and the polynomial kernel, defined by Eq. 1, was applied. For the ε=0.01 value, the following optimal hyper-parameters were obtained: C=400, a=1, c_0=1, d=4. The number of support vectors was 85 (in this case all the learning points acted as support vectors). For the value of bias we obtained -0.3879. According to these parameter values, the result of SVR can be formulated by Eq. (3):

$$y(\bar{z}) = \sum_{i=1}^{85}\left(\alpha_i - \alpha_i'\right) \cdot \left(\bar{z} \cdot \bar{x}_i + 1\right)^4 - 0.3879 \tag{3}$$

Coefficients α_i and α_i' are given by the software for the indices belonging to the support vectors. Using this formula, we can estimate the value of the share of renewable energy in total energy consumption at any point of the domain determined by the input data. The same method was applied for the region determined by the USD 16,000-30,000 GDP per capita range.

At two typical points of the region belonging to the GDP per capita range USD 30,000-45,000, and at one typical point of the region belonging to the GDP per capita range USD 16,000-30,000 the local relationship between the data (Fig. 4) was investigated.

The highlighted points are the following:
- USD 34,000 GDP per capita and 2 percent R&D expenditures in GDP;
- USD 40,000 GDP per capita and 3 percent R&D expenditures in GDP;
- USD 22,000 GDP per capita and 1 percent R&D expenditures in GDP.

On the one hand, the value of GDP per capita was fixed and the effect of the change of R&D expenditures was examined (Fig. 6, 8, and 10). On the other hand, the value of R&D expenditures was fixed and the effect of the change of GDP per capita was analyzed (Figs. 7, 9, and 11).

At each level of GDP per capita examined, the higher level of R&D expenditures means a higher rate of renewable energy consumption. This relationship shows the outstanding significance of a country's policy in the area of research and development. In considering the role of GDP per capita, the form of the charts varies, and there is no obvious connection with the share of renewable energy in total energy consumption.

5. Conclusions

In this study the support vector regression model is used as a possible approach to examine the relationship between the ratio of renewable energy consumption in total energy consumption, gdp per capita and R&D expenditures on two groups of European Union countries.

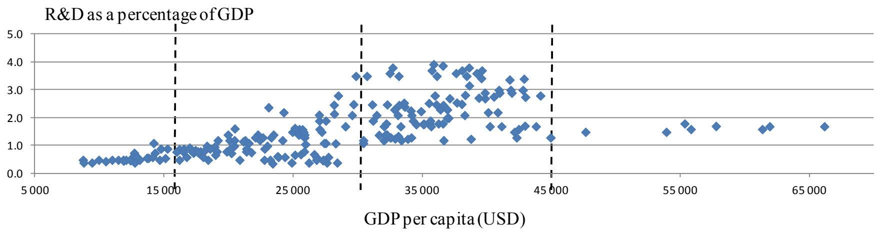

Fig. 4. Distribution of (GDP per capita, R&D expenditures) pairs

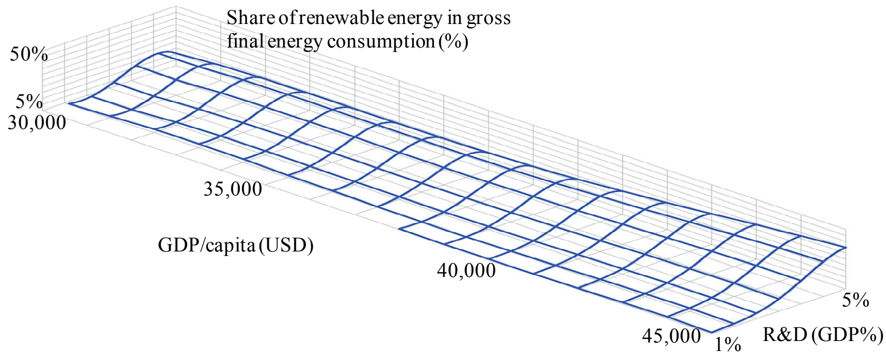

Fig. 5. Surface provided by SVR for the range USD 30,000-45,000 GDP per capita

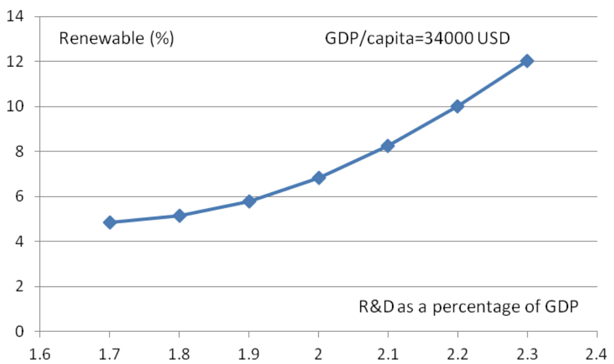

Fig. 6. The effect of the change of R&D expenditures on the share of renewable energy in total energy consumption when GDP per capita is USD 34,000 and R&D expenditures are in the range 2±0.4 percent of GDP

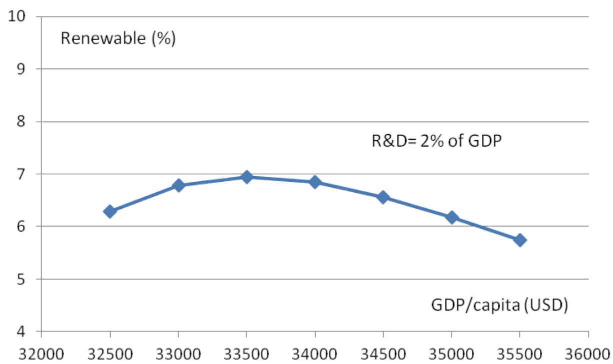

Fig. 7. The effect of the change of GDP per capita on the share of renewable energy in total energy consumption when R&D expenditures are 2 percent of GDP and GDP per capita is in the range USD 34,000±2000

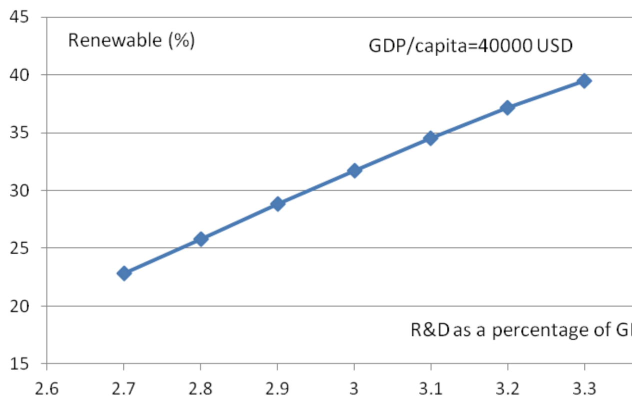

Fig. 8. The effect of the change of R&D expenditures on the share of renewable energy in total energy consumption when GDP per capita is USD 40,000 and R&D expenditures are in the range 3±0.4 percent of GDP

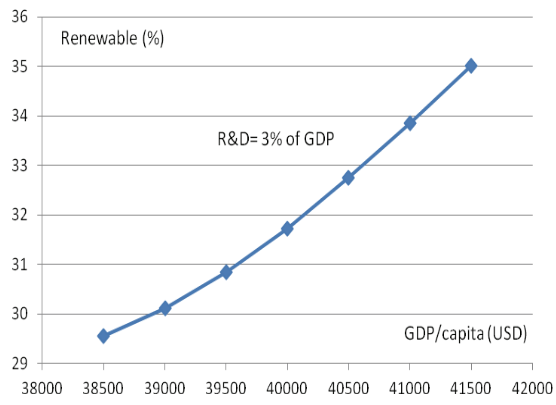

Fig. 9. The effect of the change of GDP per capita on the share of renewable energy in total energy consumption when R&D expenditures are 3 percent of GDP and GDP per capita is in the range USD 40,000±2000

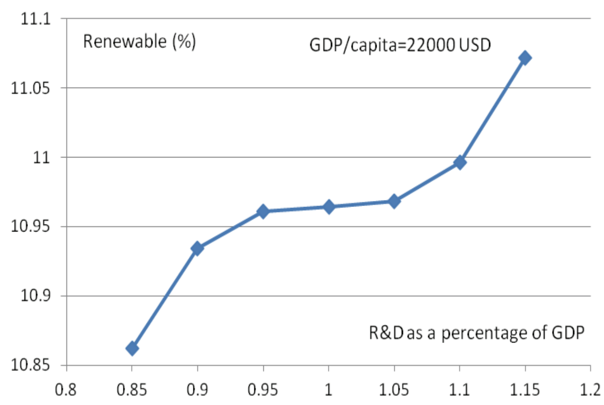

Fig. 10. The effect of the change of R&D expenditures on the share of renewable energy in total energy consumption when GDP per capita is USD 22,000 and R&D expenditures are in the range 1±0.2 percent of GDP

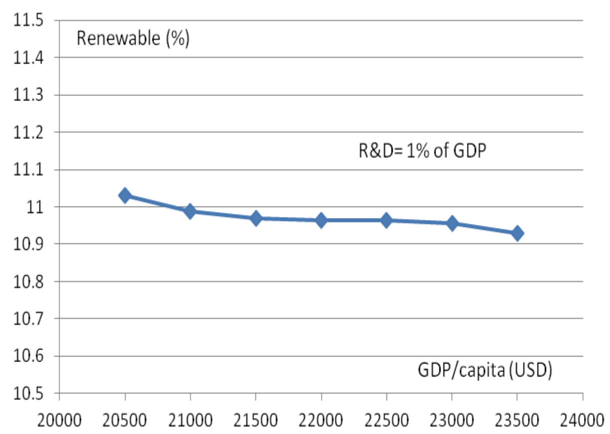

Fig. 11. The effect of the change of GDP per capita on the share of renewable energy in total energy consumption when R&D expenditures are 1 percent of GDP and GDP per capita is in the range USD 22,000±2000

We analyzed the impact of GDP and R&D expenditures on renewable energy consumption separately. A positive relationship was found between R&D expenditures and renewable energy consumption at different levels of GDP.

The examination of the effect that GDP has on renewable energy consumption at different fixed levels of R&D expenditure shows that the impact of GDP is positive at a larger level of R&D expenditure. However, the impact of GDP on renewable energy consumption is not clear at lower levels of R&D expenditure.

Acknowledgments

The publication is supported by the TÁMOP-4.2.2.A-11/1/KONV-2012-0041 project. The project is co-financed by the European Union and the European Social Fund.

References

Akkemik K.A., Göksal K., (2012), Energy consumption-GDP nexus: Heterogeneous panel causality analysis, *Energy Economics*, **34**, 865-873.

Cortes C., Vapnik V., (1995), Support vector networks, *Machine Learning*, **20**, 273-297.

Eurostat, (2014a), Statistics, Environment and Energy. Energy,, On line at: http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_31&plugin=1.

Eurostat, (2014b), Statistics, Sustainable Development indicators, Innovation, competitiveness and eco-efficiency,, On line at: http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&plugin=1&language=en&pcode=tsdec320.

Fallahi F., (2011), Causal relationship between energy consumption (EC) and GDP: A Markov switching (MS) causality, *Energy*, **36,** 4165-4170.

Guillet R., (2010), Energy and economical growth: overview and global challenges, *Environmental Engineering and Management Journal*, **9**, 1357-1362.

Haykin S., (2009), *Neural Networks and Learning Machines*, Prentice Hall, Upper Saddle River, N.J., USA.

HCSO, (2014), Per capita GDP, based on purchasing power parity, Hungarian Central Statistical Office, International Statistics, On line at: http://www.ksh.hu/stadat_annual_7.

Kum H., Ocal O., Aslan A., (2012), The relationship between among natural gas energy consumption, capital and economic growth: Bootstrap-corrected Causality tests from G-7 countries, *Renewable and Sustainable Energy Reviews*, **16,** 2361-2365.

Meyer D., Dimitriadou E., Hornik K., Weingessel A., Leisch F., (2014), e1071: Misc Functions of the Department of Statistics (e1071), TU Wien. R package version 1.6-2, On line at: http://CRAN.R-project.org/package=e1071.

Ohler A., Fetters, I., (2014), The causal relationship between renewable electricity generation and GDP growth: A study of energy sources, *Energy Economics*, **43,** 125-139.

Payne J.E., (2010), Survey of the international evidence on the casual relationship between energy consumption and growth, *Journal of Economic* Studies, **37**, 53-95.

Payne J.E., (2011), On Biomass Energy Consumption and Real Output in the US, *Energy Sources, Part B: Economics, Planning, and Policy*, **6,** 47-52.

R Core Team, (2013), R: A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria, On line at: http://www.R-project.org/.

Soytas U., Sari R., (2003), Energy consumption and GDP: causality relationship in G-7 countries and emerging markets, *Energy Economics*, **25**, 33-37.

Vaona A., (2012), Granger non-causality tests between (non)renewable energy consumption and output in Italy since 1861: The (ir)relevance of structural breaks, *Energy Policy*, **45**, 226-236.

Wang Y., Wang Y., Zhou J., Zhu X., Lu G., (2011), Energy consumption and economic growth in Cina: A multivariate causality test, *Energy Policy*, **39,** 4399-4406.

Wong S.L., Chang Y., Chia W.M., (2013), Energy consumption, energy R&D and real GDP in OECD countries with and without oil reserves, *Energy Economics*, **40**, 51-61.