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Consumption of Renewable Energy and Economic Growth

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Abstract. The significance of renewable energy is highly recognized all over the world. However, the impact of consuming renewable energy on the economy is very often disputable and contravercial. The paper explores links between consumption of renewable energy, economic growth, trade, capital and labour. The study covers 28 European Union countries for the period from 1990 to 2012. Energy has been considered as one of production factors, which has a great impact on output. Thus, the neo-classical Cobb-Douglas function has been employed to reach the aim of the article. Following the relevant state-of-art, economic growth, consumption of renewable energy, trade, capital and labour are considered as separate factors. The analysis indicates that consumption of renewable energy boots economy in 12 countries out of 28. The neutrality hypothesis has been confirmed in 2 countries, while the conservation hypothesis has been proved in 6 cases. The weakest links between the consumption of renewable energy and other factors has been noticed in Luxembourgh's case.

Keywords: renewable energy, sustainability, economic growth, and employment.

JEL Classification: O44, Q42.

Conference topic: Modern Business Management Problems and Perspectives.

Introduction

Energy consumption, its efficiency is very often associated with country's competitiveness in the international area, especially industry. Since the industrial revolution people have been trying to reduce production cost and increase profitability. One way to reduce production cost is to use cheaper energy sources. Thus, for a long time producers have been using coal, later oil as primary energy sources. Even currently, production of electricity mostly has been based on fossil fuels (Saidi, Mbarek 2016). However, fossil energy sources might run out much sooner as it is expected. Even more, burning fossil fuels raises CO_2 level, which is recognised as exerting a negative impact on the environment and causes the greenhouse effect (Sarkis, Tamarkin 2008). Thus, this resulted to search for alternative energy sources, such as biomass, wind power, photovoltaic, biofuels, geothermal energy, solar thermal energy, biogas, waste, heat pump and small hydro power (Dvorak *et al*. 2017). Meanwhile, Saidi and Mbarek (2016) claim that future relies on nuclear and renewable energy. They state that the expansion of production technologies based on nuclear energy and renewable energy would significantly reduce future emissions of greenhouse gases emissions. Wind energy as one the most perspective renewable energy sources is seen by Italian scientists. Savino *et al*. (2017) state that although big wind power plants have reached a relative maturity; however there is a lack of research on profitability of medium wind turbines and their environmental perspective. Meanwhile, Bortolini *et al*. (2014) claim that small and medium size wind power plants require more investment compared to large ones. Thus, the cost of electricity made by small and medium size wind power plant rises. As Sebri (2015) notes that the sharp and continuous increase in energy prices, the global warming, and running out primary energy sources require that renewable energy would be appropriately managed and used to sustain economic development. Nevertheless, the most of the studies prove that consumption of energy stimulate economic growth, however, at the same time even renewable energy causes environmental degradation. Moreover, renewable energy sometimes is a vital strategic decision for the countries, which have limited fossil energy resources and are dependent on other energy importing countries. The worst situation is when a country becomes reliable on the one particular energy importing country (de Arce *et al*. 2012). For example, Furouka (2017) notices that the Baltic countries concern energy sustainability because these countries have limited resources and currently they are net importers of oil and natural gas, mainly from Russia.

The aim of the paper is to analyse the relationship between consumption of renewable energy and economic growth. Few additional factors, which might be affected by the consumption of energy, have been included in the study.

Literature review

A great number of empirical studies focusing on the nexus between energy consumption and economic growth has been published since 1970s the pioneering study by Kraft, A. and Kraft, J. (1978). However, Tiba and Omri (2017) have been analysing 264 globally published scientific sources from 1978 to 2014 and state that various studies provide paradoxes and non-conclusive results which energy consumption might boost economic growth through the productivity enhancement and at the same time it can cause environmental damages.

The nexus between consumption of energy and economic growth is structured around four hypotheses: growth, conservation, feedback, and neutrality. Sebri (2015) quantify synthesises empirical literature by using meta-analysis approach and notices that 32.6% of all studies confirm both feedback and conservation hypotheses have been supported in 12.6% of all analysed cases; neutrality and growth hypotheses have been equally proved in 27.4% of studies. Dogan (2016) claims that different results in studies occur due to selected methodology. He notices that majority of the existing studies use aggregate energy consumption and thus fail to identify the effects of energy consumption by sources on economic growth.

The growth hypothesis suggests that the energy plays a vital role in economic growth directly, so an increase (decrease) in the use of energy leads to an increase (decrease) in the growth of an economy (Dogan 2016). There is unidirectional causality relationally running from energy use to income. Aslan and Ocal (2016) the meaning of growth hypothesis define as the reduction of energy consumption or energy conservation policies, which reduce energy consumption, has a destructive impact on economic growth. Aslan (2016) examines the causality relations among economic growth, biomass energy, employment and capital in the U.S. between 1961 and 2011. The findings of this study support growth hypothesis as the consumption of biomass energy has positive impact on economic growth for the U.S. Inglesi-Lotz (2016) confirms growths hypothesis as well. In the case of OECD countries, the influence of renewable energy consumption or its share to the total energy mix to economic growth is positive and statistically significant. Rafindadi and Ozturk (2016) find that a 1% increase in renewable energy consumption in Germany would boost its economy by 0.2194%.

According to the conservation hypothesis, the consumption of energy performs a vital role in economic development in both directly and indirectly way. Thus, in this case, there is unidirectional nexus running from economic growth to consuming energy. It means that the reduction of energy use will not affect economic growth adversely. Furouka (2017) analyses the situation in the Baltic States from 1990 to 2011 and confirms the conservation hypothesis. Thus, in the Baltic States the economic development causes the expansion of renewable electricity consumption, but not vice versa.

The feedback hypothesis confirms the existence of bidirectional relationship between output and energy use. This relationship suggests that energy conservation have a negative impact on economic growth and vice versa (Aslan, Ocal 2016). Kahia *et al*. (2017a) prove existence of bidirectional causal relationship between economic growth and both renewable and non-renewable energy in long-term. However, in MENA countries bidirectional causal association is confirmed between economic growth and renewable energy in short and long term while bidirectional causal relationship between economic growth and non-renewable energy exists only in long-term. Shahbaz *et al.* (2016) also confirm feedback hypothesis while analysing the consumption of biomass energy and economic development in BRIC countries. The results of this study show the presence of long-run equilibrium relationship between variables. Saidi and Mrabek (2016) discover bidirectional causality between renewable energy and real GDP per capita in the long run and prove unidirectional causality between consumption of renewable energy and real GDP per capita in the short run. Thus, Saidi and Mrabek (2016) conclude that renewable energy is a crucial element for economic growth. Meanwhile, they do not find any links between nuclear energy and real GDP per capita, but unidirectional causality exists between the consumption of nuclear energy and labour. Bidirectional long-term causality between consumption of renewable energy and economic growth has been found in China for the period from 1977–2011. Lin and Moubarak (2014) state that consumption of renewable energy boots economic growth (Fig. 1). Amri (2017) analyses the relationship between economic growth, renewable energy, trade and income by dividing all countries into three groups as per the level of development: whole, developing, high-income developing, upper middle-income developing, lower middle-income developing, lower-income developing, developed, major developed, and others developed countries. The results of study show the feedback linkage between the variables, which means that they are interdependent. In this case, Amri (2017) proves that in both developing and developed countries renewable energy consumption leads to economic growth. A 1% increase in consuming renewable energy would boost economic growth by 0.873% in developed countries and by 0.678% in developing countries.

The neutrality hypothesis denies causal relationship between consumption of energy and economic growth. Under the neutrality hypothesis, the energy consumption reduction will not adversely affect economic growth (Aslan, Ocal 2016).

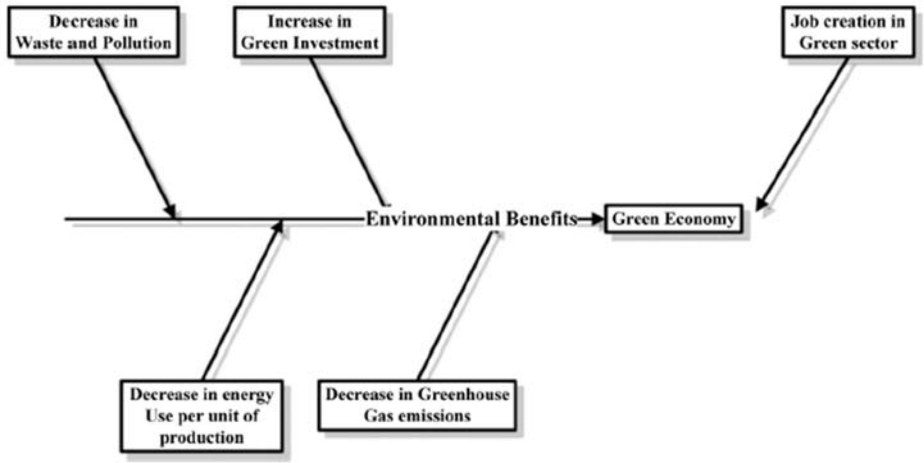

Fig. 1. Progress towards Green Economy (*Source*: Zeb *et al.* 2014)

Bhattacharya *et al*. (2016) confirm the existence of long-run dynamics between economic growth and traditional energy sources, while consumption of renewable energy has positive significant impact on economic growth only in 57% of all cases. The analysis of Naseri *et al*. (2016) shows that the increasing consumption of renewable energy in OECD countries leads to economic growth. The same positive affect has been proved in the economy of new EU members (Kahia *et al*. 2017b). Meanwhile, in OECD countries over the period of 1980–2011, Salim *et al.* (2014) discover the existence of bidirectional causality between industrial output and consumption of renewable and non-renewable energy. However, this study shows that unidirectional causality exists between the economic growth and renewable energy. The other group of scientists (Al-Mulali *et al*. 2014) claims that consumption of electricity from renewable sources is more significant to economic growth then consumption of non-renewable electricity. Al-Mulali *et al*. (2014) investigate different groups of countries classifying them according to level of incomes: high-income, upper middle income, and lower middle-income countries. However, this analysis provides quite controversial results. The feedback hypothesis is confirmed in 79% of all cases, 19% of cases prove neutrality hypothesis and the other 2% of the countries unveil a one-way long run relationship from economic growth to renewable energy consumption, in this way the conservation hypothesis is being confirmed. Zeb *et al*. (2014) explore the short and long run causality relationship among electricity production from renewable energy sources, carbon dioxide and depletion of natural resources, poverty and economic growth in SAARC countries over the period of 1975–2010. Bidirectional Granger causality between carbon dioxide emission and natural resources depletion in Nepal and between energy consumption and poverty in Pakistan has been found. Meanwhile, in Bangladesh and India, Granger causality runs from energy consumption to poverty, and from poverty to energy consumption in Sri Lanka. Antonakakis *et al*. (2017) prove that the effects of the various types of energy consumption on economic growth and CO_2 emissions are heterogenours on the various groups of countries. According to Furouka (2017), a country's income and wealth increase if consumption of the renewable electricity expands. This assumption is based on that wealthier countries are able to allocate additional human and financial resources to support their efforts to increase the share of renewable electricity consumption.

Data and Methodological Framework

The different studies apply various methods for exploring the nexus between economic growth and energy (Table 1). After meta-analysis of empirical studies, Tiba and Omri (2017) notice that Granger causality procedure is the most commonly used tool for exploring the nexus between economic growth and energy consumption. The other researchers use generalized method of moments (Ito 2017), Toda-Yamamoto test (Yildirim *et al*. 2012), ARDL (Aslan 2016; Naseri *et al*. 2016; Ito 2017) or ordinary least square method (OLS) model. Hence, Zeb *et al*. (2014) for examining the short-run and long-run causality relationship among energy consumption, CO_2 emissions, GDP, and poverty employ modified ordinary least square model – FMOLS. Ito (2017) explores relationship between CO_2 emission, economic growth, and renewable and non-renewable energy for developing countries by employing GMM and pool mean group (PMG). The PMG estimator is based on the ARDL model, which was introduced by Pesaran *et al*. (1999). Meanwhile, Antonakakis *et al*. (2017) investigate interrelations in the output-energy-environment nexus by applying panel vector regression (PVAR) and impulse response function on energy consumption (measured as kilotons of oil equivalent per capita), CO_2, and real GDP per capita in 106 countries over the period 1971–2011.

In a bulk number of studies the energy consumption has been included into neo-classical Cobb-Douglas production function (Amri 2017; Kahia *et al.* 2017b; Koçak, Sarkunesi 2017; Bhattacharya *et al*. 2016; Dogan 2016; Inglesi-Lotz 2016; Rafindadi, Ozturk 2016; Bloch *et al*. 2015; Shahbaz *et al*. 2015; Lin, Moubarak 2014). Naseri *et al*. (2016) determine energy as a factor of production as it has a great impact on output.

Table 1. The summary of previous studies on renewable energy consumption and economic growth
(*Source*: composed by the authors)

Authors	Countries	Period	Methodology	Confirmed hypothesis
Kraft, J. and Kraft, A. (1978)	USA	1947–1974	Granger causality test	Conservation hypothesis
Apergis and Payne (2010)	20 OECD countries	1985–2005	Heterogeneous panel model	Growth hypothesis
			Granger causality test	Feedback hypothesis
Yildirim *et al.* (2012)	USA	1949–2010	Toda-Yamamoto test	Conservation hypothesis only for biomass-waste-derived energy
				Neutrality hypothesis for other renewable energy sources
Marques and Fuinhas (2012)	24 European countries	1990–2007	Panel data	Neutrality hypothesis
Al-Mulali *et al.* (2013)	103 countries	1980–2009	FMOLS	79% of the countries confirmed feedback hypothesis; 19% – neutrality hypothesis; 2% – conservation hypothesis
Lin and Moubarak (2014)	China	1977–2011	Cobb-Douglas function	Feedback hypothesis
Zeb *et al.* (2014)	SAARC	1975–2010	FMOLS	Conservation hypothesis
Salim *et al.* (2014)	OECD countries	1980-2011	Panel co-integration techniques	Feedback hypothesis confirmed for industrial output and renewable and non-renewable energy
			Granger causality test	Growth hypothesis
Bloch *et al.* (2015)	China	1977–2013	Cobb-Douglas function Autoregressive distributed lag VECM	Growth hypothesis
Aslan and Ocal (2016)	New EU countries	1990–2009	ARDL and asymmetric causality test	Bulgaria confirms growth hypothesis, Cyprus, Estonia, Hungary, Poland and Slovenia – neutrality hypothesis, Czech Republic – conservation hypothesis
Naseri *et al.* (2016)	OECD countries	1990–2012	Time series linear pattern with Johansen co-integration test and ARDL model	Growth hypothesis
Inglesi-Lotz (2016)	OECD countries	1990–2010	Cobb-Douglas function	Growth hypothesis
Bhattacharya *et al.* (2016)	Top 38 renewable energy consuming countries	1997–2012	Cobb-Douglas function	57% of all cases confirm growth hypothesis
Destek (2016)	Brazil, India, Turkey, South Africa, Mexico, Malaysia	1971–2011	Asymmetric causality approach	Neutrality hypothesis confirmed for Brazil and Malaysia, growth hypothesis for South Africa and Mexico, feedback hypothesis for India
Aslan (2016)	USA	1961–2011	ARDL approach	Growth hypothesis
Shahbaz *et al.* (2016)	BRIC countries	1991–2015	Cobb-Douglas function	Feedback hypothesis
Antonakakis *et al.* (2017)	106 countries	1971–2011	PVAR and impulse response function	Feedback hypothesis
Koçak and Sarkgunesi (2017)	9 Black sea and Balkan countries	1990–2012	Cobb-Douglas function with panel co-integration	Feedback hypothesis
Kahia *et al.* (2017a)	MENA oil importing countries	1980–2012	Granger causality test	Feedback hypothesis
Kahia *et al.* (2017b)	MENA countries	1980–2012	Cobb-Douglas function	Feedback hypothesis

Some recent studies integrate energy consumption by sources (renewable and non-renewable energy consumption) with the production function (Bhattacharya *et al*. 2016; Dvorak *et al*. 2017). Shahbaz *et al*. (2016) into Cobb-Douglas production function include economic growth expressed as real GDP, consumption of biomass energy, gross capital formation and trade openness. Meanwhile, Inglesi-Lotz (2016) by employing Cobb-Douglas production function includes labour, capital and total factor productivity. Destek (2016) defines real GDP as output; combustible, renewable and waste energy is expressed as the percentage of total energy; the capital is determined by real gross fixed capital, and labour as total employment.

The aim of this research is to provide links between renewable energy consumption, economic growth, trade, and labour force. The study explores 28 European Union countries over the period 1990 to 2012. Following the relevant state-of-the-art, economic growth, renewable energy consumption, trade, capital and labour are considered as separate factors. To reach the aim of the paper, the Cobb-Douglas production function is used:

$$y_{it} = f\left(E_{it}; L_{it}; K_{it}; T_{it}\right); \tag{1}$$

$$y_{it} = AE_{it}^{\beta_{1i}} L_{it}^{\beta_{2i}} K_{it}^{\beta 3i} T_{it}^{\beta 4i}, \tag{2}$$

where: i – stands for the number of cross-sections, t – time period, y – domestic output, *E, L, K, T* indicate renewable energy, labour, capital, and trade respectively; A – shows level of the technology utilised in the country.

In order to linearize the form of non-linear Cobb-Douglas function, all time series are converted into logarithms. The transformation of data series into natural logarithm avoids the problems associated with dynamics properties of the data series. The log transformation of the data series is preferred approach as cache resulting coefficient in a regression evaluation can be interpreted as elasticity (Bhattacharya *et al*. 2016).

The empirical equation to investigate the relationship between renewable energy consumption and economic growth is modelled keeping technology as constant. The log-linear specification to assess relationship between renewable energy and economic growth is as follows:

$$\ln y_{it} = \alpha + \beta_{1i} \ln E_{it} + \beta_{2i} \ln L_{it} + \beta_{3i} \ln K_{it} + \beta_{4i} \ln T_{it} + \varepsilon_{it}, \tag{3}$$

where lny_{it}, lnE_{it}, lnL_{it}, lnK_{it}, lnT_{it} represent logarithms of real GDP per capita, renewable energy consumption (% of total final energy consumption), employment level, gross fixed capital and exports of goods and services in Euros. β_{1i}, β_{2i}, β_{3i}, β_{4i} are elasticities of output with the respect to renewable energy, labour, gross fixed capital and trade, ε_{it}-is the error term which supposed to be independently and normally distributed.

All data was obtained from Eurostat database.

Empirical findings

First results revealed that Sweden, compared to the other European Union countries, would consume the most of renewable energy. The expected ratio is 38.58% of total energy consumption. The second largest mean among EU countries is in Latvia case (31.8) followed by Finland and Portugal. The least part of consuming renewable energy as the part of final energy is in Malta (0.44). Meanwhile, the highest deviation is noticed in Estonia (7.10), followed by Romania (6.36) and the neighbouring countries Latvia (6.27) and Lithuania (6.46) (Table 2). Lowest deviation has been registered in Malta, France and Luxembourg, which show that the data points would close to expected value.

R and R^2 tests revealed that the model is significant in all cases and explains more than 90% of all variability in lnY (Table 3). The results are provided by 1% of significance. The simulation of equation 3 shows that consumption of renewable energy in 12 out 28 EU countries would stimulate economic growth. This indicates the growth hypothesis. The neutrality hypothesis is confirmed in Portugal's case, as it does not have relationship between economic growth and renewable energy. The correlation coefficient is only 0.027. The conservation hypothesis is confirmed in Czech Republic case. In this case, the elasticity's estimation shows that 1% increase in consuming renewable energy would shrink real GDP per capita by 0.012%, decrease employment level by 0.253% and capital formation would drop by 0.094. However, in this case trade would increase by 0.876%. High correlation coefficients confirm the significance of renewable energy.

The strongest relationship (indicated by correlation coefficient) between the consumption of renewable energy and real GDP has been noticed in Czech Republic (0.932), Denmark (0.930), Germany (0.922), Netherlands (0.939) and Slovak Republic (0.942) (Table 4). However, the renewable energy has major impact on real GDP per capita in Netherlands while the lowest effect of renewable energy on economic growth is in Luxembourg. In this case the increase of renewable energy consumption by 1% would shrink economic growth by 0.022%. The correlation coefficient shows that between consumption of renewable energy and all other factors real GDP per capita, labour, capital, trade are very weak links in Luxembourg case. For example between the consumption of renewable energy and real GDP per capita this coefficient only 0.263, even lower coefficient is between consumption of renewable energy and labour (0.042). Thus, it might be stated that in Luxembourg the economic growth is boosted by other factors or other business sectors.

Table 2. Descriptive statistics of renewable energy consumption in the European Union countries
(*Source*: composed by the authors)

	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Std. Error	Statistic
EU	6.08	14.14	8.7679	0.53991	2.41457
Austria	22.57	31.46	26.5206	0.63245	2.75680
Belgium	0.94	5.46	2.3048	0.34054	1.48436
Bulgaria	1.92	14.37	7.1387	0.94597	4.12337
Cyprus	0.33	7.42	3.2413	0.48376	2.10866
Croatia	12.38	21.49	16.4105	0.53936	2.35102
Czech Republic	2.56	10.24	5.8787	0.48955	2.13391
Demark	7.05	23.95	12.7322	1.26725	5.52380
Estonia	3.36	25.13	16.2307	1.62958	7.10317
Finland	24.13	39.12	29.9704	0.89678	4.01051
France	8.57	12.59	10.3195	0.27277	1.21985
Germany	1.97	12.38	5.6680	0.80988	3.62189
Greece	7.02	13.90	8.5407	0.36885	1.64956
Hungary	3.87	10.19	5.9670	0.41306	1.84724
Ireland	1.90	7.09	3.1803	0.37458	1.67516
Italy	3.78	12.09	6.0264	0.53744	2.40352
Latvia	17.57	40.37	31.8494	1.40373	6.27766
Lithuania	2.89	24.28	14.7291	1.44524	6.46331
Luxembourg	1.27	6.85	2.9664	0.31534	1.41025
Malta	0.13	2.61	0.4406	0.12387	0.55398
Netherlands	1.16	4.65	2.3030	0.27438	1.22706
Poland	2.06	11.08	6.8175	0.54168	2.42245
Portugal	18.07	27.82	23.5336	0.62615	2.80025
Romania	3.35	24.10	14.6060	1.42434	6.36984
Slovak Republic	2.09	10.48	5.9045	0.62364	2.78901
Slovenia	10.23	19.32	14.3234	0.55192	2.46828
Spain	7.29	15.75	9.9180	0.55094	2.46390
Sweden	31.35	49.91	38.5848	1.31157	5.86551

Although in Austria, the consumption of renewable energy would have positive impact; however, an increase of renewable energy by 1%, would boost economic growth only by 0.079%. Even more, the correlation coefficient in Austria's case indicates moderately strong relationship (0.660).

Table 3. Results of Equation 3 (*Source*: composed by the authors)

	Energy	Labour	Capital	Trade	R	R^2
EU	–0.130 (–0.487)	0.103 (0.556)	–0.848 (–0.966)	1.825 (0.925)	0.949	0.874
Austria	0.079 (0.561)	–0.115 (0.785)	–0.525 (–1.604)	1.477 (4.024)	0.954	0.910
Belgium	0.427 (1.853)	–0.059 (–1,195)	–0.727 (–1.265)	1.327 (3.235)	0.950	0.903
Bulgaria	0.230 (0.893)	–0.026 (–0.148)	0.741 (2.329)	0.052 (0.501)	0.967	0.935
Cyprus	–0.113 (–0.495)	0.465 (2.809)	0.306 (2.173)	0.414 (1.752)	0.952	0.905

Continued Table 3

	Energy	Labour	Capital	Trade	R	R^2
Croatia	–0.115 (–2.353)	0.148 (2.617)	0.157 (1.688)	0.914 (10.329)	0.987	0.974
Czech Republic	–0.012 (–0.045)	–0.253 (–2.287)	–0.094 (–0.406)	0.876 (3.022)	0.967	0.935
Demark	0.231 (0.477)	0.251 (1.799)	–0.878 (–1.656)	1.456 (1.671)	0.961	0.923
Estonia	0.191 (1.514)	0.294 (4.080)	0.621 (9.104)	0.411 (3.761)	0.985	0.971
Finland	0.194 (0.854)	0.020 (0.060)	0.423 (0.672)	0.338 (0.839)	0.927	0.860
France	0.218 (1.872)	0.207 (0.664)	0.031 (0.053)	0.699 (1.907)	0.943	0.888
Germany	0.220 (0.514)	–0.149 (–1.833)	–0.226 (–1,746)	0.895 (1.788)	0.950	0.902
Greece	–0.135 (–1.422)	0.490 (2.866)	–0.135 (–0.409)	0.686 (2.190)	0.950	0.903
Hungary	–0.417 (–1.375)	–0.031 (–0.376)	0.267 (0.970)	1.056 (2.12)	0.962	0.928
Ireland	–0.431 (–1.352)	–0.248 (–0.553)	0.410 (0.915)	1.109 (2.966)	0.966	0.932
Italy	0.118 (1.130)	0.166 (0.637)	0.637 (1.400)	0.115 (0.379)	0.952	0.907
Latvia	–0.331 (–2.651)	0.060 (0.828)	0.547 (6.866)	0.779 (7.355)	0.983	0.967
Lithuania	–0.157 (–0.712)	0.035 (0.325)	0.333 (3.210)	0.852 (4.616)	0.976	0.952
Luxembourg	–0.022 (–0.252)	–0.078 (–0.600)	–0.218 (–0.506)	1.241 (2.736)	0.959	0.919
Malta	0.427 (3.845)	–0.287 (–1.893)	0.438 (2.691)	0.055 (0.299)	0.927	0.859
Netherlands	0.559 (1.610)	0.424 (1.803)	–0.596 (–1.821)	0.595 (0.904)	0.966	0.933
Poland	–0.125 (–1.142)	–0.290 (–4.353)	–0.713 (–4,476)	1.666 (10.185)	0.985	0.970
Portugal	–0.300 (–1.784)	0.073 (0.584)	–0.586 (–1.690)	1.404 (5.211)	0.955	0.911
Romania	–0.424 (–2.145)	0.004 (0.037)	–0.184 (–1.504)	1.516 (4.764)	0.981	0.953
Slovak Republic	0.090 (0.596)	–0.078 (–1.448)	0.014 (0.133)	0.855 (4.944)	0.983	0.967
Slovenia	–0.387 (–2.156)	0.140 (1.079)	0.965 (3.620)	0.185 (0.639)	0.945	0.892
Spain	–0.245 (–1.707)	0.434 (1.987)	0.983 (3.444)	–0.280 (–1.371)	0.973	0.966
Sweden	–0.040 (–0.153)	–0.090 (–0.784)	0.617 (2.770)	0.443 (1.982)	0.941	0.886

The lowest long-term bivariate correlation coefficient exists in Luxembourg followed by Croatia, France and Portugal. In most of cases, the strongest links are noticed between renewable energy and trade. The most notable negative impact out of all EU countries, renewable energy would have on the economic growth in Hungary, Ireland, Latvia and Slovenia, where 1% of decrease on consuming renewable energy would shrink economic growth by 0.417%, 0.431%, 0.331%, and 0.387% respectively. Moreover, the correlation coefficient indicates moderately strong links between renewable and real GDP per capita in these countries, 0.703, 0.648, 0.681, and 0.613 respectively. The weakest links between the consumption of renewable energy and other factors in long-term have been registered in Croatia. Even elasticity shows that increase in consuming 1% of renewable energy would decline economic growth by 0.113%. However, such low correlation coefficients confirm the neutrality hypothesis in Croatia case. Although, 16 out of EU countries have negative elasticity of lnE; however, in some cases, the correlation coefficient between renewable energy and trade indicate strong relationship in long-term period, which means that renewable energy might have positive influence on the economic growth in the future.

Table 4. Correlation coefficient between renewable energy and other independent factors (*Source*: composed by the authors)

	GDP	Labour	Capital	Trade
EU	0.874	0.684	0.888	0.925
Austria	0.660	0.783	0.521	0.639
Belgium	0.871	0.880	0.926	0.881
Bulgaria	0.894	0.256	0.869	0.531
Cyprus	0.812	0.736	0.734	0.863
Croatia	–0.201	0.261	–0.303	–0.084
Czech Republic	0.932	–0.745	0.938	0.963
Demark	0.930	0.212	0.849	0.955
Estonia	0.787	–0.662	0.701	0.863
Finland	0.840	0.431	0.793	0.892
France	0.233	0.093	0.166	-0.014
Germany	0.922	–0.005	0.632	0.972
Greece	0.361	0.470	0.529	0.429
Hungary	0.703	–0.191	0.636	0.895
Ireland	0.648	0.424	0.750	0.790
Italy	0.685	0.433	0.586	0.631
Latvia	0.681	–0.632	0.748	0.824
Lithuania	0.864	–0.724	0.814	0.910
Luxembourg	0.263	0.042	0.190	0.266
Malta	0.652	–0.163	0.399	0.224
Netherlands	0.939	0.770	0.855	0.947
Poland	0.812	–0.434	0.833	0.877
Portugal	0.027	–0.407	–0.473	0.056
Romania	0.821	–0.423	0.745	0.912
Slovak Republic	0.942	–0.412	0.849	0.942
Slovenia	0.613	0.388	0.829	0.938
Spain	0.492	0.352	0.729	0.438
Sweden	0.871	0.127	0.880	0.851

On the whole, in the EU the consumption of renewable energy and economic growth has strong relationship; however the growth of consuming renewable energy by 1% would shrink EU economic growth by 0.130%. The strong relationship has been registered between consumption of renewable energy and trade, capital formation. However, moderately strong link has been indicated between renewable energy and employment level in EU.

Conclusions

The analysis of various scientific studies provides controversial results. Moreover, different results have been obtained by analysing the same countries over the same period of time. This might be explained that different scientists employ different methodology. The study on employed methods has revealed that the most popular are Granger causality test, AFD test and Cobb-Douglas production function transform into natural logarithm form.

Based on analysis of various methods, Cobb-Douglas production function has been applied for the study. Results of R and R^2 have shown that the created model is significant in all cases. The analysis indicates that consumption of renewable energy boosts economic growth in 12 countries out of 28. However, the opposite result has been noticed in the case of European Union economy. Although, correlation coefficient indicates strong relationship between consumption of renewable energy and real GDP per capita of EU; however a 1% increase of renewable energy would shrink all economy by 0.13%.

The growth hypothesis has been confirmed in 12 cases, the neutrality hypothesis has been indicated in Luxembourg, Portugal. The conservation hypothesis has been proved in Czech Republic, Hungary, Latvia, Lithuania, Romania, and Spain cases.

The results reveal that almost in all cases the strongest relationship has been registered between consumption of renewable energy and trade. Meanwhile, the other factors demonstrated different links with consumption of renewable energy.

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