The impact of development of the renewable energy sector in the EU on the energy – growth nexus

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Abstract

The aim of the study is to assess the impact of development of the renewable energy sector on the relations between renewable and non-renewable energy consumption and economic growth in the EU countries. First, two groups of EU member countries with different levels of development of their renewable energy sectors are identified. Then, the dynamic common correlated effect estimator proposed by Chudik and Pesaran (2015) is used in order to estimate the error correction models in both groups of countries as well as in all EU countries. The results reveal that the level of development of the renewable energy sector influences energy-growth nexus. The findings on long-term output elasticities suggest that both renewable and non-renewable energy plays a significant role in economic growth in countries with a relatively high level of development of the renewable energy sector. The results obtained for a short-term perspective indicate bidirectional causal relations in this group. In the other group only non-renewable energy consumption influences economic growth.

Keywords: *renewable energy, economic growth, EU countries, dynamic common correlated estimator*

JEL Classification: C33, C38, Q43

1 Introduction

During the last two decades European Union countries experienced a significant change in the distribution of their energy consumption. The total primary energy supply (TPES) from renewable energy sources (RES) rose from 84.6 Mtoe in 1995 to 210.0 Mtoe in 2015, with an average annual growth rate of 9.5 per cent. At the same time, TPES from non-renewable energy sources (including coal, oil, gas and nuclear sources) decreased from 1583 Mtoe in 1995 to 1402 Mtoe in 2015. Over this period, the share of renewable energy sources in TPES grew from 5.1 per cent to 12.9 per cent. The largest part of renewable energy sources in TPSE came from biofuels and waste, which accounted for about 64.4 per cent of the renewable energy supply in 2015.

Although the share of "new" renewables in EU countries increases rapidly, they still constitute only a small portion of overall energy consumption (in 2015 the share of wind

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energy in TPES amounted to 1.6%, and the share of solar energy in TPES to 0.8%). What is more, EU countries differ in their development of “new” renewable energy sources. The data provided by EurObserv’ER's (2015) barometers indicate three areas of importance of renewable energy development in economy, i.e. the share of employment, investments and turnover in renewable energy in the total economy, which makes it possible to distinguish countries with reference to their share of the renewable energy sector in economy in the last several years. Obviously, the larger the share of renewable energy in economy is, the more significant its interrelations with economy should be. The question of interest is, however, whether the renewable energy sector is large enough to exert a noticeable impact on economy. Our study could be placed among numerous papers (see for e.g. Ozturk, 2010; Smyth and Narayan, 2015; Śmiech and Papież, 2014; Tiba and Omri, 2017) which focus on energy consumption-growth nexus. However, as we distinguish renewable and non-renewable energy consumption (like Bhattacharya, 2016, Apergis and Payne, 2012), the results obtained in our study give a more detailed picture of the relations than the results obtained in other papers.

The objective of the paper is to assess the impact of development of the renewable energy sector in economy on the relationship between renewable and non-renewable energy consumption and economic growth in the EU countries. In order to examine this impact, first, two groups of countries with a similar level of development of the renewable energy sector are identified. Next, the modern panel econometric tools are applied to uncover the energy (renewable and non-renewable) – growth nexus within the groups. The analysis is based on the annual panel data in EU member countries from the period 1995–2014.

The study is divided into two stages. The aim of the first one is to identify countries with a similar level of development of the renewable energy sector. In order to measure the significance of this sector in national economies, three variables - employment, turnover and investment - are used, and the *k*-means method is used to identify groups of similar countries.

During the second stage, dynamic error correction models are applied to investigate causality between (renewable and non-renewable) energy consumption and economic growth, and Cobb-Douglas production function is used as a theoretical framework. The analysis is conducted within the groups obtained in the first step, as well as for the whole sample. This stage consists of several steps, each of which is based on econometric methodology allowing for cross-sectional dependence.

The paper contributes to the existing literature in three main aspects.

First, our analysis is one of the first attempts directed at describing the relationship between renewable and non-renewable energy consumption and economic growth in

EU countries. Second, we notice that the share of the renewable energy sector in the EU economy is still limited, but, at the same time, considerable differences between countries can be noticed. Thus, the empirical strategy we employ takes into account a potential impact of the level of development of the renewable energy sector on the relations we analyse. Third, we apply a modern panel econometric approach including the dynamic common correlated effect estimator proposed by Chudik and Pesaran (2015), which allows for commonly observed cross-sectional dependence and potential heterogeneity in a panel of countries.

2 Methodology

To test for the presence of such cross-sectional dependence in our data, we apply Pesaran's (2004) cross-sectional dependence (CD) test, with the null hypothesis claiming no cross-sectional dependence. Next, the panel unit roots tests are applied. We investigate the possible non-stationarity property of the data by applying second-generation panel CIPS unit root test recently proposed by Pesaran (2007), which allows for cross-sectional dependence. The second generation cointegration tests developed by Westerlund (2007) are used, as they take into account cross-sectional dependencies. The long-term relationship between the renewable and non-renewable energy consumption and economic growth is concluded from the Cobb-Douglas production function, as it is convenient in the field. In order to estimate the equations, the Common Correlated Effects estimator (henceforth CCE) proposed by Pesaran (2006), which is robust to the presence of cross-sectional dependence, is used. During the final step of the analysis, the error correction model is estimated with the use of Chudik and Pesaran (2015) dynamic common correlated effect estimator with heterogeneous coefficients.

3 Data

The assessment of the impact of development of the renewable energy sector in economy on the relationship between renewable and non-renewable energy consumption and economic growth is based on the annual panel data. The analysis covers the period 1995–2015 and takes into account 26 European Union member countries (Cyprus and Malta are excluded).

The dataset used to determine the level of development of the renewable energy sector in economy includes three variables. The first variable is the share of employment in renewable energy technologies in total employment (from 15 to 64 years) in each European Union country (EMP). The second variable denotes the share of combined turnover of renewable energy sectors in GDP (in current prices) in each European Union country (TURN). The third variable describes the share of asset finance (investment) in the newly built capacity for all renewable energy sectors in GDP (in current prices) in each European Union country (INVEST). The data on employment, turnover and asset finance are obtained from the EurObserv'ER barometers (2011-2015). Taking into account access to data (the data have been recorded since 2010), we use all available records from the period between 2010 and 2014. In order to establish the engagement of particular countries in the renewable industry (economy), we calculate average values from the period 2010-2014.

The second stage of our study is devoted to the analysis of the relations between renewable and non-renewable energy consumption and economic growth. In order to study these relations, we use real gross domestic product per capita (variable: GDP) in constant 2010 U.S. dollars obtained from the World Development Indicators (World Bank, 2016). Energy consumption from non-renewable energy sources (variable: NREC) and energy consumption from renewable energy sources (variable: REC) are represented by energy use in kg of oil equivalent per capita. These data are obtained from the European Commission websites[4]. As the analysis is conducted using the Cobb-Douglas production function, a set of variables is extended to include two more: real gross capital formation per capita (K) in constant 2010 U.S. dollars as a proxy of capital and labour force participation rate (% of total population aged 15+) (L). Both variables come from the World Development Indicators (World Bank, 2016). All variables are in natural logarithms.

4 Empirical results and discussion

The first stage of the analysis is aimed at finding groups of countries with a similar level of development of their renewable energy sectors. The groups are identified by comparing three variables: the employment in renewable energy sector in total employment (EMP), the share of turnover of renewable energy sector in GDP (TURN), and the share of investments in renewable energy sector in GDP (INVEST). All variables are initially standardized. To visualize the arrangement of countries relevant to these three variables, principal component analysis is applied, and its results are reported in Table 1. The first principal component (PC1) represents the common impact of all three variables. The larger the part of economy related to renewable energy (i.e. more employment in renewable energy sector, larger turnover, more investment in RES), the smaller the value of the PC1. The PC2 represents the contrast between employment and investment in the renewable energy sector. Both PCs represent

[4] Energy datasheets: EU-28 countries (https://ec.europa.eu/energy/en/data-analysis/country, accessed on 28.02.2017 r.

about 82 per cent of total variance. The PC3 shows the contrast between turnover and other two variables (EMP, INVEST).

	PC1	PC2	PC3
EMP	-0.599	-0.536	0.595
TURN	-0.718	-	-0.695
INVEST	-0.354	0.844	0.404
Cumulative variance	0.460	0.817	1.000

Table 1. The results of principal component analysis.

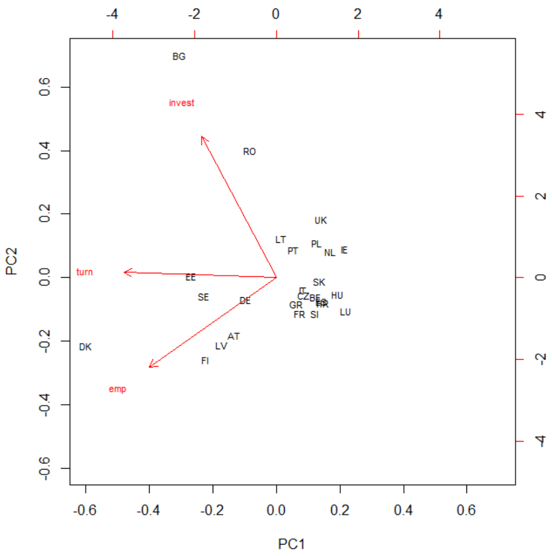

Fig.1. Biplot for variables representing countries' involvement in renewable energy.

The biplot presented in Fig.1 demonstrates the distribution of countries related to the first two principal components. There is a homogeneous group of countries with a positive value of the first principal component, and moderate values of the second principal component. The group consists of countries which, in general, have a low share of the renewable sector in economy. In the remaining countries at least one of the variables is larger than average. Thus, these countries could be seen as the ones which develop their renewable energy sectors most noticeably. Finally, the *k*-means method is employed, and the division (into two groups) observed in the biplot is confirmed.

The first group (GROUP 1) consists of Austria, Bulgaria, Denmark, Germany, Estonia, Finland, Latvia, Romania, and Sweden. The second group (GROUP 2) includes the remaining countries.

The analysis of the relations between non-renewable and renewable energy consumption and economic growth is conducted for both groups (GROUP 1 and GROUP 2) as well as for all European countries (ALL). In order to formally examine the presence of cross-sectional dependence, Pesaran's (2004) cross-sectional dependence (CD) test is used. The CD test statistics are highly significant, so our conclusion is that each series exhibits cross-sectional dependence[5]. The results of the CIPS unit root test proposed by Pesaran (2007) confirm that at least three of the time series are non-stationary, and the Westerlund (2007) cointegration test confirms the existence of the long-term relationship between economic growth and non-renewable and renewable energy consumption[6]. Next, the cointegrating vector is estimated, and the results of the estimation of the long-term relationship are reported in Table 2, which presents the results obtained for CCE MG method proposed by Pesaran (2006).

All variables are expressed in natural logarithms, and the estimated coefficients can be interpreted as long-term elasticity. The empirical findings for all European countries (ALL) (see Table 2) reveal that long-term elasticities of non-renewable energy and renewable energy consumption are equal to 0.124 and 0.039, respectively. Similarly, in countries from the first group (GROUP 1), which display a relatively high level of development of the renewable energy sector, long-term elasticities of non-renewable energy and renewable energy consumption are equal to 0.086 and 0.062, respectively. The coefficients are significant at the 5 per cent level, and the signs of these four variables are positive and follow our expectations for both energy proxies. In turn, the results obtained for the countries from the second group (GROUP 2) (see Table 2), which are characterized by very low employment, turnover and investment in the renewable energy sector, indicate that a one-per cent increase in non-renewable energy consumption increases output growth by 0.117 percentage points.

During the final step of the analysis we estimate a panel vector error correction model using dynamic CCE estimator (Chudik and Pesaran, 2015) to investigate Granger causality between the variables. Table 3 demonstrates F-statistics and t-statistics, which are useful in the short- and long-term Granger causality analyses for all European countries (ALL), countries from the first group (GROUP 1), and countries from the second group (GROUP 2),

[5] Detailed results of the CD test are available from the authors upon request.
[6] Detailed results of Pesaran (2007) as well as Westerlund's panel cointegration tests (2007) are available from the authors upon request.

respectively. For all specifications the results reveal that the estimated coefficients of the error correction terms are all statistically significant (with one exception, see Table 3) and negative (as expected). These results indicate that all variables used in this study respond to deviations from the long-term equilibrium.

Statistics	ALL	GROUP 1	GROUP 2
NREC	**0.124*** **	**0.086*** **	**0.117** **
REC	**0.039** **	**0.062** **	**0.022**
K	0.195***	0.183***	0.223***
L	0.190	0.281	-0.103
const	2.796	1.731	0.383
CD Statistic	1.92*	-1.95*	-1.50
CIPS test for residuals CADF(0)	-12.655***	-9.085***	-11.342***

Notes: The Pesaran (2006) CCE MG is estimated using the Stata “xtdcce2” command. ***, ** indicate statistical significance at 1, and 5 per cent level of significance, respectively.

Table 2. Panel Cointegration Estimation Results. (Cointegration regression).

The results reported in Table 3 indicate the lack of causality between renewable and non-renewable energy consumption and economic growth in all European countries. Thus, they confirm the neutrality hypothesis, which states that renewable and non-renewable energy consumption and economic growth are independent and do not affect each other in the short-run. Similar results for renewable energy consumption and economic growth are obtained by Menegaki (2011).

However, the results reveal bidirectional causality between the economic growth and renewable energy consumption in the countries belonging to the first group (GROUP 1), which means that their renewable energy consumption and economic growth are mutually dependent. Additionally, we demonstrate that development of the renewable energy sector, i.e. employment growth and the increase in turnover and investment in this sector, have an impact on economic growth. Thus, the results confirm the neutrality hypothesis between non-renewable energy consumption and economic growth.

The results obtained in the countries from the second group (GROUP 2) confirm the feedback hypothesis between non-renewable energy consumption and economic growth only at the 10 per cent level of significance. It means that economies in these countries can be called ‘non-renewable energy dependent’, and that non-renewable energy consumption can play an important role in their economic growth and vice versa. However, we find no causality between renewable energy consumption and economic growth, which confirms the neutrality hypothesis.

Dependent variable	Source of causation (independent variables)			
	Short term - F-statistics			Long term - t-stat
	ΔGDP	**ΔNREC**	**ΔREC**	ECT_{t-1}
ALL				
ΔGDP	-	1.67	1.75	-4.98***
ΔNREC	0.90	-	0.53	-4.86***
ΔREC	1.58	0.83	-	-3.33***
GROUP 1				
ΔGDP	-	0.67	**6.11****	-3.54***
ΔNREC	1.58	-	2.54	-5.59***
ΔREC	**7.25*****	0.51	-	-4.44***
GROUP 2				
ΔGDP	-	2.75	0.34	-1.04
ΔGDP[a]	-	**3.63***	0.02	-
ΔNREC	**3.12***	-	2.92*	-2.66***
ΔREC	1.24	0.26	-	-3.42***

Notes: Regression with 1 lag estimated by the panel DCCE (Chudik and Pesaran, 2015) using the Stata “xtdcce2” command (see: Ditzen, 2016). ***, **, * indicate statistical significance at 1, 5 and 10 per cent level, respectively. a As the coefficient of ECT in ΔGDP equation is insignificant, as robustness check we present the result of Eq. 3a when error-correction term ECT is excluded.

Table 3. Panel Granger causality test results.

Conclusions

The objective of the study is to assess the impact of the level of development of the renewable energy sector in the EU on the relationship between renewable and non-renewable energy consumption and economic growth. Our findings can be summarised in four points.

First, we find that Austria, Bulgaria, Denmark, Germany, Estonia, Finland, Latvia, Romania, and Sweden are the countries with the relatively well-developed renewable energy sectors. In comparison to other countries, they have both larger turnover and larger investment stock in the renewable energy sector.

Second, the findings on long-term output elasticities suggest that, along with traditional inputs, such as capital and labour force, both renewable and non-renewable sources play a significant role in the process of economic development in countries with a relatively high level of development of the renewable energy sector. In countries with a relatively low level of development of the renewable energy sector only non-renewable sources play a significant role in their economic development.

Third, the feedback hypothesis is confirmed for the group of countries with a relatively high level of development of the renewable energy sector, which means that renewable energy consumption and economic growth are mutually dependent in countries belonging to this group.

Forth, in the second group of countries, which are characterized by a low level of development of the renewable energy sector in economy, the relationship between renewable energy consumption and economic growth is not confirmed. The feedback hypothesis for non-renewable energy consumption and economic growth is confirmed only for this group. It means that economies in these countries can be called ‘non-renewable energy dependent’, and exclusively non-renewable energy consumption plays an important role in their economic growth.

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