Is development of the renewable energy sector crucial for the electricity consumption-growth nexus in the EU countries?

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Abstract

The aim of the study is to assess the impact of development of the renewable energy sector in the EU on the relationship between renewable and non-renewable electricity consumption and economic growth in the period 1995-2015. In order to identify countries with reverence of development of their renewable energy sector statistical clustering methods are applied. The relations between renewable and non-renewable electricity consumption and economic growth are investigated within the panel VAR framework.

The results reveal that the level of development of the renewable energy sector is crucial for linkages between electricity consumption and economic growth. In a group of countries with a relatively high level of development of the renewable energy sector, renewable electricity consumption and economic growth are mutually dependent. Additionally, the increase in economic growth leads to a short-term increase in renewable electricity consumption. At the same time, the rise in renewable electricity consumption is helpful in increasing economic activity. In the remaining countries renewable electricity consumption and economic growth are independent.

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1 Introduction

Most studies investigating single countries confirm the impact of electricity consumption on GDP (Gurgul and Lach, 2012; Marques et al., 2018), or GDP on electricity consumption (Baranzini et al., 2013). Recently observed flourishing of renewable energy attracts the attention of researchers who analyse the renewable energy-growth nexus. Rafindadi and Ozturk (2017) study the relation in Germany, which is a leading renewable energy user in Europe. They find that renewable energy consumption in Germany consolidates the country's economic growth prospects and boosts German economic growth. However, the results obtained for other (European) countries or groups of countries are not so unambiguous (an

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extensive review of literature devoted to relationships between energy, environment and economic growth can be found in Tiba and Omri's, 2017). In Menegaki's (2011) analysis of European countries no relation is found between economic growth and renewable energy consumption in Europe. As she explains, it could result from the uneven and still insufficient exploitation of renewable energy sources across Europe. Similarly, the analysis of linkages between electricity consumption and GDP for many countries does not yield consistent results (Wolde-Rufael, 2014), although the growth hypothesis is confirmed for selected countries (Costa-Campi et al., 2018). However, to the best of our knowledge, none of the papers has so far addressed the direction of causality in the electricity consumption-growth nexus in relation to the level of development of the renewable energy sector in the EU member countries.

The objective of the paper is to assess the impact of the level of development of the renewable energy sector on the relationship between renewable and non-renewable electricity consumption and economic growth in the EU countries. Since the trend of the electrification of economy (Marques et al., 2018) is so prominent, we decide to base our study on electricity consumption instead of energy consumption, which is a prevailing tendency in literature. It is in line with Otzurk's (2010) survey, in which he states that electricity consumption "is a limiting factor to economic growth". Moreover, we decide to divide the overall electricity consumption into renewable and non-renewable electricity consumption, as the first component corresponds to 'new' renewables. This way we attempt to assess the relations between 'new' renewables and economic growth. Being aware of the limitations listed in Menegaki (2011), we decide to divide the EU countries into two groups according to the level of development of their renewable energy sectors. In order to distinguish the groups, we use aclustering method and the data provided by EurObserv'ER's(2015) barometers, which include employment, investment, and turnover in the renewable energy sector in the EU countries. Obviously, the larger the share of renewable energy sector in economy is, the more significant its interrelations with economy should be. In general, the study is dedicated to verification of four hypotheses (the growth hypothesis, the conservation hypothesis, the feedback hypothesis, and the neutrality hypothesis) for the energy consumption-growth nexus, which have important implications for energy policy.

The analysis of the relationship between renewableand non-renewable electricity consumption and economic growth is based on the annual panel data from the period 1995 – 2015. However, the actual level of development of the renewable energy sector in the EU countries measured between 2010 and 2015. The data are obtained from the EurObserv'ER's barometers (2011-2016). The analysis consists of two main stages. The aim of the first stage is

to identify countries with differentlevels of development of their renewable energy sectors. Clustering is conducted by k-means methods, assuming two groups of countries. In the second stage, dynamic panel modelsare applied to investigate causality between renewable and nonrenewableelectricity consumption and economic growth. The analysis is conducted within the groups of countries obtained in the first step. To uncover the links between renewable and non-renewable electricity consumption and economic growth, the panel VAR model is implemented.

The paper contributes to the existing literature in three main aspects. First, our analysis is (to the best of our knowledge)the only attempt devoted to studying the relationship between renewable and non-renewable electricity consumption and economic growth in the EU countries. Second, as noticed by Menegaki(2011),the EU countries are highly diversified, thus the empirical strategy we employ takes into account a potential impact of development of the renewable energy sector on the relationships we analyse. Any relations between renewable electricity consumption and economic growth observed for the group of countries with a relatively high level ofdevelopment of the renewable energy sector could become important premises for other countries. Third, we apply a universal econometric framework, i.e. the panel VAR model, which allows not only for observing Granger causality, frequently used in literature, but also for studying the impulse response function.

2 Methodology

Clustering is conducted by k-means, which is one of the most frequently used methods. The k-means procedure consists of several steps in which objects are relocated into classes (whose number is given). The procedure is interrupted and the groups are established if there are no further relocations of any object. As the procedure is sensitive to the initial choice of seed clusters, it is repeated 500 times with different choices of seeds in order to obtain optimal results.

In order to investigate the relations panel VAR framework is applied. A reduced form of panel VAR of order p with a panel specific fixed-effect model can be represented by the system of linear equations:

$$Y_{it} = A_1 Y_{it-1} + A_2 Y_{it-2} + \dots + A_p Y_{it-p} + u_i + e_{it}, \text{ for } i \in \{1, 2, \dots N\}, t \in \{1, 2, \dots, T\}$$
(1)

where: Y_{it} is a (1*xk*) vector of variables ($\Delta \ln GDP_{it}$, $\Delta \ln REL_{it}$, $\Delta \ln NREL_{it}$, $\Delta \ln K_{it}$, $\Delta \ln L_{it}$), u_i is fixed effects and e_{it} is idiosyncratic errors, while $A_1, A_2, ..., A_p$ are (*kxk*) matrixes of model parameters to be estimated. It is assumed that innovations have the following characteristics: $E[e_{it}]=0, E[e'_{it}e_{it}]=\Sigma$ and $E[e'_{it}e_{is}]=0, t > s$. The last assumption indicates a model without dynamic interdependencies. Finally, it is assumed that VAR is stable, which means that all characteristic roots lie outside the unit circle (Lütkepohl, 2005). The advantage of the panel VAR model with fixed effects is that all unobservable time invariant factors at a country level can be captured. It is important, as factors which describe a renewable potential of a particular country (wind intensity, solar radiation), and characteristics critical to economic growth (country size, population), are used in the analysis. The fixed effect indicators impose a challenge when estimation is considered, since they are correlated with lagged regressors. As a consequence, the mean-differencing procedure commonly applied to eliminate fixed effects would create a bias. To avoid the problem, the Helmert procedure (Arellano and Bover, 1995) is applied, which preserves the orthogonality between transformed variables and lagged regressors, so lagged regressors are used as instruments and the coefficients are estimated by the system GMM.

Two applications of panel VAR are used in the study. The first one is Granger causality, based on the Wald test, applied to relations between electricity (renewable and non-renewable) consumption and economic growth. The second one is the ortogonalized impulse-response function, which shows the reaction of one variable to the innovations in another variable in the system. Since the actual variance–covariance matrix of the errors is diagonal, it is necessary to decompose the matrix and make it orthogonal. In the analysis we adopt the Choleski decomposition, which is equivalent to transforming the system in 'recursive'VAR for identification purposes. As a result, it is assumed that variables which come earlier in the ordering affect the remaining variables with lags and contemporaneously, while the variables that come later affect only the variables with lags.

3 Data and empirical results

The assessment of the impact of development of the renewable energy sector on the relationship between renewable and non-renewable electricity consumption and economic growth is based on the annual panel data. The analysis covers the period 1995-2015 and takes into account 26 EU countries. The actual level of development of the renewable energy sector in the EU countries is measured between 2010 and 2015⁴ using three variables: the employment in renewable energy sector sharein total employment (EMP), the turnover in the renewable energy sector sharein GDP (TURN), and the investments in the renewable

⁴No data from the earlier period are available.

energysector sharein GDP (INVEST) in each EU country. These data are obtained from the EurObserv'ER's barometers (2011-2016). In order to study the relationships between renewable and non-renewable electricity consumption and economic growth we use:GDP - real gross domestic product per capita in constant 2010 US dollars, REL and NREL -gross electricity generation from renewable (or non-renewable) sources in TWh per capita, respectively, K - real gross capital formation per capita in constant 2010 US dollars and L - the labour force participation rate (% of total population aged 15+). All variables are in natural logarithms.

The groups are identified by comparing three variables: EMP, TURN, and INVEST. All variables are initially standardized. The k-means method is employed to find two clusters in the EU countries related to the share of the renewable energy sector. The first group (GROUP 1) include following countries: Austria, Bulgaria, Denmark, Germany, Estonia, Finland, Latvia, Romania, Swedenand the second group (GROUP 2) include: Belgium, Croatia, the Czech Republic, France, Greece, Hungary, Ireland, Italy, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, the United Kingdom (see also Papież et al., 2017). The first group (GROUP 1) includes countries with the relatively welldeveloped renewable energy sectors. In comparison to other countries, they have both larger turnover and larger employment in this sector. These countries not only have higher average values of EMP (0.92% in comparison to 0.38%), but are also much more diversified with respect to EMP (standard deviation equals 0.43% for the first group and 0.13% for the second group). The situation is similar when TURN is considered. The first group has decidedly higher values of TURN, but their diversity is slightly lower than in case of employment. The highest value of TURN is observed in Denmark (4.01%), while in Germany it is three times lower (1.25%). Smaller differences between the groups are observed in INVEST. In both groups there are countries with no INVEST, e.g. Latvia (GROUP 1) and Croatia (GROUP 2). High values of investment in RES are noted in Bulgaria (1.00%). The first group is rather heterogeneous with reference to investment, with clear outlier values for Bulgaria and Romania (in which high INVEST accompanies very low EMP) and Denmark (with the highest EMP and TURN and relatively low INVEST).

The analysis of the relationships between renewable and non-renewable electricity consumption and economic growth is conducted for both groups (GROUP 1 and GROUP 2).Before the final panel VAR models are estimated, the dynamic properties of the data are analysed. First, the data are examined for cross-sectional dependence using Pesaran's (2004) cross-sectional dependence (CD) test. As the result confirms cross-sectional dependence, the

tests applied next incorporate this assumption. The second generation panel unit root tests (Pesaran, 2007) are applied to uncover the stochastic properties of the series used. The results of Westerlund's (2007) panel cointegration testsobtained for all four statistics for all specifications(GROUP 1, GROUP 2) reveal that the null cannot be rejected, which is clear evidence of the lack of the cointegration relationship between renewable and non-renewable electricity consumption and economic growth. Similar conclusions regarding economic growth, and renewableand non-renewable energy consumption for 28developedcountries are drawn by Aflonso et al. (2017).

Since the data are nonstationary, and there is no cointegration between them, the final step of the analysis uses the panel VAR estimated for first differences of the series. The modelis used to infer Granger causality relationships between renewable and non-renewable electricity consumption and economic growth. The estimation of the panel vector autoregression (VAR) model, i.e. Eq. (1) uses GMM estimator. Based on the selection criteria, we fit a second-order panel VAR model with 2 lags. Granger causality results obtained through the Wald testare presented in Table1, which includes findings obtained for the first group (GROUP 1), and the second group (GROUP 2), respectively.

Dependent variable	Source of causation (independent variables)– Chi2-statistics		
	∆lnGDP	∆lnREL	ΔlnNREL
GROUP 1			
ΔlnGDP	-	7.053**	0.639
ΔlnREL	7.418**	-	9.910***
ΔlnNREL	1.716	4.116	-
GROUP 2			
∆lnGDP	-	0.877	0.501
ΔlnREL	4.666	-	0.683
∆lnNREL	2.626	1.431	-

Table 1. Panel Granger causality test results.

Notes: The null hypothesis: no causal relationship between variables. ***, ** indicate statistical significance at 1 and 5 per cent level, respectively.

The results reported in Table 1 confirm the neutrality hypothesis between both renewable or non-renewable electricity consumption and economic growth in the countries with a relatively low level of development of the renewable energy sector (GROUP 2). In these countries changes in electricity consumptiondo not affect economic growth adversely, and vice versa:changesin economic activity do not lead to changes in electricity consumption. In contrast, the results obtained for the countries with a relatively high level of development of the renewable energy sector (GROUP 1) confirm the neutrality hypothesis only between non-renewable electricity consumption and economic growth. The results also indicate thebidirectional causality relationship between renewable electricity consumption and economic growth. These findings support the feedback hypothesis in these countries, which states that renewable electricity consumption and economic growth are mutually dependent. Thus, the results demonstrate that development of the renewable energy sector, i.e. employment growth and the increase in turnover and investment in this sector, has an impact on economic growth. Economy in these countries called 'renewable energy dependent', which means that growth of renewable electricity consumption is an important factor in their economic development.

Next, in order to identify the reaction of electricity consumption to economic growth and vice versa, the impulseresponse functions (IRF) are found using the Cholesky orthogonalization procedure. The impulseresponse functions are obtained within a band representing a 95% confidence interval estimated by Monte Carlo simulations (1000 iterations). Fig. 1 illustrate the impulseresponse functions of economic growth and renewable and non-renewableelectricity consumption to shocks (one standard deviation) to these variables. The first row of Fig. 1 shows the response of renewable electricity consumption to one standard deviation shock to economic growth and vice versa. The reaction of renewable electricity consumption to a shock to economic growth is positive but insignificant for the countries with a relatively high level of development of the renewable energy sector (GROUP 1). The increase in economic growth seems to have a positive impact on growth of renewable electricity consumption. In contrast, these reactions for the countries with a relatively low level of development of the renewable energy sector (GROUP 2) is negative but still insignificant. The reaction of economic growth to a shock to renewable electricity consumption is positive but insignificant for the countries with a relatively high level of development of the renewable energy sector (GROUP 1) as well as for all countries. This means that the advancement of the renewable electricity sector and the rise in renewable electricity consumption leads to the increase in their economic activity. But for the countries belonging to the second group the effect of a shock to renewable electricity consumption to economic growth exerts a persistent negative impact on future economic growth. The second row of Fig. 1 demonstrates the reaction of non-renewable electricity consumption to a shock to economic growth is positive and statistically significant, for all cases (i.e. for GROUP 1, GROUP 2). This indicates that the increase in economic growth positively affectsnon-renewable electricity consumption for all EU countries, although for countries with a relatively high level of development of the renewable energy sector (GROUP 1) this positive reaction is statistically significant only in the first year, and loses significance later. Also the Fig. 1 illustrates the negative and insignificant reaction of economic growth to a shock to non-renewable electricity consumption for countries with a relatively low level of development of the renewable energy sector (GROUP 2).



a) GROUP 1

b) GROUP 2



Conclusions

The two stages of the empirical strategy employed in the study prove to be effective, as the results obtained for particular groups are considerably different, although reasonable. The relations between renewable and non-renewable electricity consumption and economic growth in countries with a high level of renewable energy development are different than in the remaining countries. The greater the share of the renewable energy sector in economy (although limited), the more noticeable the relations between renewable electricity consumption and economic growth. On the other hand, the renewable energy sector in the remaining countries is too small to play a significant role in economy. In particular, our findings can be summarised in two main points.First, the feedback hypothesis between renewable electricity consumption and economic growth is confirmedfor the group of countries with a relatively high level of development of the renewable energy sector. Additionally, the results of the impulse response function suggestthat the rice in economic growth leads to a short-term increase in renewable electricity consumption and the rise in renewable electricity consumption boosts economy.

Second, in the group of countries with a low level of development of the renewable energy sector, the neutrality hypothesis between renewable or non-renewable electricity consumption and economic growth is confirmed.In general, the results obtained in the study point at an important role played by development of the renewable energy sector in establishing the relations between electricity consumption and economic growth, which can be directly translated into several relevant policy implications. The analysis suggests that, in order to find significant relations between renewable electricity consumption and economic growth, the level of development of renewable energy sector has to be large enough, which, is still not the casefor most EU countries. Another important conclusion stemming from the impulse response analysis (even though the responses described usually are not statistically significant)states that, in order to expect a positive impact of the renewable sector to economy, sufficient investments into renewable energy have to be made. If the renewable energy sector is small, it is unlikely to exert a large impact on economy. But if the renewable energy sector is larger (at least as large as in the countries from the first group), it can be reasonably expected to stimulate economy. This non-linearity lends support to the idea of enlarging the renewable energy sector.

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