Energy consumption and economic growth in the light of meeting the targets of energy policy in the EU

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***Abstract*—The aim of the paper is to assess linkages between energy consumption and economic growth in the light of compliance with the EU energy policy targets stated in the climate and energy package for 2020 in the European Union member states in the period 1993 – 2011. The study is divided into two main stages. During the first one, using cluster analysis methods, four groups of countries which met three energy policy targets stated in the package at similar levels were identified. During the second stage, the bootstrap Granger panel causality approach proposed by Konya [9] was used to verify the hypothesis of energy-growth nexus in the countries from the groups. The results obtained reveal that the level of compliance with energy policy targets influences linkages between energy consumption and economic growth. Causal relations were found in the group of countries with the greatest improvements on the EU energy policy targets.**

***Index Terms*-- Energy consumption, Macroeconomics, Econometrics.**

I. INTRODUCTION

In March 2013 the European Commission adopted a Green Paper on a 2030 framework for climate and energy policies, which initiated a discussion on common climatic targets and the ways of meeting them. The reference point for all discussions is the climate and energy package from 2008, which delineates the main targets for 2020 and specifies regulations helpful in meeting them. The strategic objectives of the EU policy (3x20) to be achieved by 2020 include: a 20% reduction in EU greenhouse gas emissions below the 1990 levels, raising the share of EU energy consumption produced from renewable resources to 20%, and a 20% improvement in the EU's energy efficiency. In the context of the EU strategy, two important questions should be asked: first, is it possible and, if so, how to reconcile climate protection and economic competitiveness, and second, to what extent climate policy influences energy consumption and, consequently, competitiveness of European economy. These issues make the assessment of the impact of energy policy on the relations between energy consumption and economic growth an important research area in environmental economics.

Subject literature abounds in studies which deal with the relationship between energy consumption and economic growth and various other parameters (e.g. [1]-[4], [7], [10]-[15], [18]-[20], [22]-[23], [25]). They analyze various countries and use various modeling methods to verify four hypotheses regarding causal relations between energy consumption and economic growth: the growth hypothesis, the conservation hypothesis, the feedback hypothesis and the neutrality hypothesis. However, to the best of our knowledge, so far causality in the growth-energy nexus in the context of meeting the targets of energy policy in the EU has not been addressed in any of them.

The aim of the paper is to assess linkages between energy consumption and economic growth in the light of compliance with the EU energy policy targets stated in the climate and energy package for 2020 in the European Union member states in the period 1993 – 2011. Additionally, the level of compliance with those energy policy targets in the EU member states in the period 1993 – 2011 will be measured.

The study was divided into two main stages. The aim of the first one was to identify the countries which met the targets of energy policy stated in the climate and energy package for 2020 at similar levels. Cluster analysis methods allowed for the objective identification of groups of such countries. During the second stage, a bootstrap Granger panel causality approach proposed by Konya [9] was used to verify the hypothesis of causality between energy consumption and economic growth in the countries from the four groups obtained during the previous stage. Homogeneity of the groups addressed the lump together problem. Since the analysis covers the period 2008-2009, the global financial crisis was also taken into account.

This study benefited from a grant by the Polish National Science Centre (project DEC-2011/03/B/HS4/01134).

The paper contributes to the existing literature in several aspects. Firstly, the analysis yielded homogeneous groups of countries with reference to three variables characteristic for energy policy stated in the climate and energy package for 2020. This allowed for the comparison of the countries with respect to the targets listed in this package including the results of the changes in the structure of energy production (a reduction of greenhouse gas emissions (GHG) and an increase of renewable energy in the gross final consumption of energy (RES)) as well as the modernization of economies (a reduction of energy intensity). Secondly, the groups obtained in the previous stage were used to develop models for the countries which met the EU energy policy targets at similar levels, that is the countries with similar dynamics of energy consumption (including renewable energy sources) and the modernization of economy. In other studies countries were grouped according to their membership in international organizations or their level of economic development or the geographic location. Such criteria were not always conductive to creating groups of homogeneous countries with reference to the relations between energy and growth nexus. If the elements of the panel are not homogeneous, 'traditional' panel models may give erroneous results of causality tests (see [24]). Thirdly, the method applied, that is the bootstrap panel causality approach proposed by Kónya [9], yielded the results that are robust to cross-sectional dependence and slope heterogeneity and do not suffer from the small-sample problem, since causality tests are based on country-specific bootstrap critical values. Additionally, this method allows for inference on dependencies in particular countries, which gives a more detailed picture than a traditional panel approach. Finally, the comparison of causal relations with the levels at which energy policy targets stated in the climate and energy package for 2020 were met revealed the conditions in which a significant relationship between energy consumption and economic growth was observed. Additionally, the analysis took into account the global financial crisis, which considerably influenced the relations between energy consumption and economic growth.

II. METHODOLOGY

The study was divided into two stages. During the first one groups of countries with similar levels of meeting energy policy targets stated in the climate and energy package for 2020 were identified. The second stage dealt with the analysis of causality between economic growth and energy consumption using a bootstrap Granger panel causality approach proposed by Kónya [9]. Causality tests were conducted in homogeneous groups obtained during the first step, which avoided the lump together problem.

Three methods were used to group the countries in the study: the k-means method and the partitioning among medoids (PAM) method proposed by Kaufman and Rousseeuw [8], and agglomerative clustering. In order to evaluate an optimal number of clusters in the data, we used internal validity indexes: Calinski-Harabasz pseudo-F index [6] and the average silhouette width [8]. The final classification of objects is, therefore, the result of the comparison of the results of respective grouping algorithms.

The choice of a suitable method allowing for the analysis of causality for panel data requires the assessment of cross-sectional dependence and slope heterogeneity. To test for the presence of cross-sectional dependence in our data, we applied two different statistics, Lagrange multiplier (*LM*) [5] and *CD* [16]. The methods developed by Swamy [21] and Pesaran and Yamagata [17] were used to test the null hypothesis of slope heterogeneity. Using Kónya's [9] approach allows for the identification of specific countries in which a Granger causal relationship occurs. His bootstrap panel causality approach has three relevant advantages. Firstly, the approach is carried out under the structure of seemingly unrelated regression (SUR) which, as demonstrated by Zellner [27], is more efficient than the OLS if cross-sections dependence occur. Secondly, the test for the direction of causality is based on the Wald tests with country-specific bootstrap critical values. That is why it does not impose a joint hypothesis across all members of the panel and specific countries in which a Granger causal relationship can be identified. Thirdly, the procedure does not require any pretesting for panel unit roots or cointegration.

III. DATA

The assessment of the impact of the level of compliance with EU energy policy targets stated in the climate and energy package for 2020 on the relationship between energy consumption and economic growth based on the annual panel data. The analysis covered the period 1993 – 2011 and took into account 25 European Union member states. As the study was divided into two stages, it was based on two sets of variables. The first one described the level of compliance with EU energy policy targets stated in the climate and energy package for 2020. The second one was used to analyze the relationship between energy consumption and economic growth.

On the basis of the main EU energy policy targets regarding climate and energy for 2020, we chose three variables identifying groups of countries where these targets were met at similar levels. The first variable refers to energy intensity of the economy in 2011 compared to 1993 (EI). The second variable denotes the dynamics of greenhouse gas emissions in 2011 compared to 1990 (GHG). The third variable (RES) describes the share of energy from renewable sources in gross energy consumption in 2011 divided by individual mandatory national targets for the share of energy from renewable sources in gross final energy consumption of energy in 2020, that is the percentage of compliance with individual mandatory national targets for the share of energy from renewable sources in 2011.

During the second stage of the study four variables from the World Development Indicators [26] were chosen for the analysis of relationship between energy consumption and economic growth: real Gross Domestic Product per capita (GDP) in constant 2005 U.S. dollars and energy consumption (EC), represented by energy use in kg of oil equivalent per capita, real gross fixed capital formation per capita (K) in constant 2005 U.S. dollars as a proxy of capital and labour force participation rate (% of total population aged 15-64) (L). All variables were in natural logarithms.

TABLE I. THE BOOTSTRAP PANEL GRANGER CAUSALITY ANALYSIS FOR EACH COUNTRY IN THE GROUP

Countries	H_0: Energy consumption does not Granger cause GDP (H_1: EC→ GDP)				H_0: GDP does not Granger cause energy consumption (H_1: GDP → EC)			
	Wald statistics	*Bootstrap critical value*			*Wald statistics*	*Bootstrap critical value*		
		10%	*5%*	*1%*		*10%*	*5%*	*1%*
GROUP 1								
Austria	5.44	12.039	17.969	31.123	0.05	11.626	19.591	30.064
Cyprus	0.13	7.427	12.343	27.336	**12.23****	7.933	10.102	15.853
Greece	**11.70****	5.863	7.623	15.123	4.59	6.712	11.032	22.318
Italy	0.99	10.812	12.744	20.690	3.30	9.385	12.666	18.283
Portugal	0.00	6.864	12.620	24.894	0.11	10.597	20.195	46.755
Slovenia	0.00	4.168	6.361	12.923	1.39	11.903	15.194	22.881
Spain	1.22	15.663	21.172	55.264	5.10	7.256	11.295	17.652
GROUP 2								
Belgium	1.18	7.601	12.405	22.537	0.19	6.035	9.912	14.818
France	0.97	5.516	7.434	11.711	**42.91*****	6.768	11.342	25.499
Ireland	0.89	7.355	11.514	26.160	2.76	14.587	24.620	37.581
Netherlands	0.47	9.222	12.572	23.548	0.51	6.022	8.665	15.842
United Kingdom	0.80	5.478	8.744	28.141	5.79	9.001	13.640	23.611
GROUP 3								
Czech Republic	0.11	18.414	27.951	41.513	0.62	3.167	4.179	6.864
Denmark	1.99	4.442	6.633	10.061	0.14	6.676	13.412	19.183
Finland	1.54	20.751	25.459	37.383	6.12	11.328	18.116	41.692
Germany	1.19	6.677	9.469	15.136	3.36	7.007	9.598	13.556
Hungary	0.01	13.657	23.552	36.855	4.11	13.674	18.895	27.484
Sweden	2.82	11.266	14.963	21.922	1.81	15.696	19.601	32.425
GROUP 4								
Bulgaria	**8.47***	6.083	8.951	19.231	**24.69****	9.338	14.618	31.737
Estonia	3.77	8.146	12.864	23.804	2.08	8.774	13.669	26.808
Latvia	**14.49****	8.883	13.084	28.327	**9.27***	7.285	11.643	27.400
Lithuania	0.06	7.458	11.272	26.290	0.40	7.884	12.427	27.472
Poland	**38.5*****	6.093	8.797	17.552	0.56	8.940	13.654	27.251
Romania	2.30	8.943	12.875	25.149	**11.36***	10.999	17.567	33.657
Slovakia	7.42	7.936	12.764	26.060	**37.83***	31.204	42.814	75.162

Note: ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. Bootstrap critical values are obtained from 10,000 replications.

IV. EMPIRICAL RESULTS AND DISCUSSION

A. *Meeting EU energy policy targets in the groups of countries*

The objective of this part of the analysis was to uncover the similarities between countries with respect to their compliance with EU energy policy targets stated in the climate and energy package for 2020. The groups were identified by comparing three variables: the reduction in energy intensity of the economy (EI), the reduction in greenhouse gas emissions (GHG), and the compliance with individual mandatory national targets for the share of energy from renewable sources (RES).

The first group includes the following countries: Austria, Cyprus, Greece, Italy, Portugal, Slovenia, and Spain. They are the countries with the lowest (compared to other groups) reduction of energy intensity of the economy (13.7%). In this group the highest increase in greenhouse gas emissions in 2011 compared to 1990 was observed (on mean 15.5%). The countries in this group met their national targets for the share of energy from renewable sources in final consumption of energy in 2020 at an average level: their mean percentage in 2011 was 70.8%.

Group 2 comprises the following countries: Belgium, France, Ireland, the Netherlands, and the United Kingdom. The reduction of energy intensity in this group was highly diversified, and the mean value of this variable was 30.7%. The reduction of greenhouse gas emissions in the countries belonging to this group was very low (the mean was 10.1%). In comparison to other countries, the countries in this group met their national targets for the share of energy from renewable sources in final consumption of energy in 2020 at the lowest level, with the average value of this variable being only 35.9% that is almost twice lower than its average value in other groups.

The third group includes the Czech Republic, Denmark, Germany, Finland, Hungary, and Sweden. The level of reduction of energy intensity in the period 1993-2011 in this group was similar to Group 2. In 2011 the average reduction in energy intensity compared to 1993 was 32.4%. The 20% reduction of greenhouse gas emissions in 2011 compared to 1990 was also high. The countries in this group displayed a high level of compliance with national targets for the share of renewable energy consumption in total energy consumption.

Group 4 consists of the following countries: Bulgaria, Estonia, Latvia, Lithuania, Poland, Romania, and Slovakia. They obtained the best results as far as the targets of EU

energy policy are concerned. They displayed the highest reduction of energy intensity in the period 1993-2011 - 54.4%. They also had the highest reduction of greenhouse gas emissions in 2011 compared to 1990 (42.5%). The share of renewable energy consumption in total energy consumption (84.1%) in the countries from this group was not lower than in countries from other groups. It is worth noting that the countries in this group not only met two out of three targets (as did countries from Group 3), but also exceeded them.

B. Bootstrap panel Granger causality

The first step in analyzing panel data Granger causality consisted of testing for cross-sectional dependence and slope heterogeneity. The results indicate that for all groups of countries we rejected the null hypothesis indicating no cross-sectional dependence between analysis variable. Similarly, we observe that tests rejected the null hypothesis of slope homogeneity for each group of countries. For each system of (SUR) equations, the number of lags was chosen according to the AIC criterion. Additionally, specifications incorporating a deterministic trend were taken into account. To eliminate the effects of the global financial crisis, dummy variables which were only unity at the period of crisis and zero otherwise. It was assumed that a country could be affected by the crisis for 1 year (2008), for 2 years (2008-2009), for 3 years (2008-2010), or for 4 years (2008-2011). The AIC criterion was used to check which dummy variable should be used.

Table 1 reports the results obtained from the analysis of 25 European Union countries divided into 4 groups. The number of countries in the first three groups, where causality between energy consumption and economic growth was observed, was not high. The first 3 groups included the countries with the low or average reduction of energy intensity of the economy in the period 1993-2011 and the low or average reduction in greenhouse gas emissions in 2011 compared to 1990, or even the increase in greenhouse gas emissions in 2011 compared to 1990 (Group 1).

Among the countries from these 3 groups only in Cyprus (Group 1) and France (Group 2) test statistics revealed (at 0.05 and 0.01 significance level) unidirectional causality running from economic growth to energy consumption. So, the findings support the conservation hypothesis for these countries, which claims that the changes in energy consumption stem from the changes in economic activity, and energy conservation policy does not negatively affect economic growth. Therefore, Cyprus and France are countries in which economy is not entirely energy dependent. The results also indicate that only in one country in these groups i.e. in Greece (Group 1) the presence of (at the significance level 0.05) unidirectional causality from energy consumption to economic growth (the growth hypothesis) signals that economy is energy dependent. Thus, energy conservation policies may have an adverse impact on economic growth there. In such cases, economy is called ‘energy dependent’ and energy conservation policies may be implemented with adverse effects on real GDP. There is lack of any causal relationships in the third group.

The results obtained in the remaining countries (15 countries out of 18) in the first three groups indicate the lack of Granger causality between energy consumption and economic growth, so they confirm the neutrality hypothesis. This means that energy conservation policies do not exert an adverse impact on economic growth, and, at the same time, energy consumption is not affected by economic performance. That is why in these countries energy conservation policies would not have any impact on real GDP. Such results allow policy makers to develop energy policies that are not dependent on economic activity in these countries. A likely explanation of the lack of causality is that energy consumption is a relatively small component of GDP, which is connected with the fact that the share of industry sector in these countries was relatively low in the whole period covered by our study.

The situation in the last group of countries was different. In two countries, Bulgaria and Latvia, the feedback hypothesis was confirmed, which means that energy consumption and economic growth are mutually dependent there. The presence (at the significance level 0.01) of bidirectional causality between energy consumption and economic growth supports the feedback hypothesis, stating that an energy policy oriented toward improvements in energy consumption efficiency may not have an adverse impact on economic growth. In three countries, Poland, Romania, and Slovakia, unidirectional causality was observed. In Poland it was unidirectional causality from energy consumption to economic growth. Thus, the results confirm the growth hypothesis in Poland (at the significance level 0.01), which means that the growth of energy consumption is an important element of their economic development. In case of Romania and Slovakia unidirectional causality at the 0.1 significance level from economic growth to energy consumption (the conservation hypothesis) was confirmed.

The confirmation of the growth hypothesis, the conservation hypothesis, and the feedback hypothesis for most countries (5 out of 7) in group 4 can result from several factors. Firstly, especially at the initial period of the analysis, industry played a significant role in their economies, while services were not so important. That is why economies of these countries were more energy dependent. Secondly, industry, including the energy sector, was at first very inefficient and intensive. Thirdly, countries in this group made the greatest progress in increasing energy efficiency, increasing the share of renewable energy sources and reducing greenhouse gas emissions, which could be attributed to their substantial expenditures on modernization. On the other hand, modernization leads to the increase of their competitiveness and the pace of their economic growth.

V. CONCLUSIONS AND POLICY IMPLICATIONS

The aim of the study was to assess the impact of the level of compliance with the EU energy policy targets stated in the climate and energy package on the relationship between energy consumption and economic growth. By investigating this issue, the study contributed to the discussion on the EU climate and energy policy for 2030 focusing on the possibility of reconciling ambitious climatic strategies with promoting economic growth and competitiveness of economies of the EU member states.

The aim was achieved in two stages. During the first one, the EU member states were grouped according to their compliance with the EU energy policy targets stated in the climate and energy package for 2020. Next, the relationship between energy consumption and economic growth was assessed for each country separately with the use of Kónya's procedure [9]. Cluster analysis yielded 4 groups of countries with similar levels of compliance with the EU energy policy targets, which were then used to analyze causality between energy consumption and economic growth.

The analysis of causality revealed different patterns of causal relations in different groups. In the groups with the low or mean reduction of energy intensity of the economy and the low or mean reduction of greenhouse gas emissions in 2011 (or even the growth of greenhouse gas emissions in 2011 compared to 1990), no significant causal relations were observed in 15 out of 18 countries. However, in the group of countries with the highest level of compliance with the EU energy policy targets, causal relations were found in 5 out of 7 countries. It should be noted that huge progress observed in this group was possible, among others, because in 1993 energy intensity in these countries was much higher than in remaining groups. It was caused by a specific structure of economy and inefficient production systems prevalent in post-communist countries. Despite intensive modernization, mean energy intensity in 2011 in group 4 was similar to mean energy intensity in the remaining groups in 1993.

It remains to address the issue of the connection between the results obtained in our study and attempts to reconcile climate protection with competitiveness of economy. Let us assume that in most EU member states there are no linkages between energy consumption and economic growth, thus limiting energy consumption in these countries will not have an adverse effect on their economies. As far as other countries are concerned, it seems that causality between energy consumption and economic growth observed in them was caused by the transformation of their economies and intensive modernization of their industries. Since now their energy intensity has reached the levels of other countries from the initial period of the study, it can be assumed that there are no reasons for further connections between energy-growth nexus, and that it will be possible to reconcile climate protection with competitiveness of their economies in those countries.

On 22 January 2014 the Commission proposed the framework for climate and energy policy after 2020. Although meeting the targets stated in it will certainly generate certain burdensome social or political costs, our findings lead to the conclusion that the reforms should not adversely affect economy.

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