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Determinants of renewable energy development in the EU countries. A 20-year perspective

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ABSTRACT

The objective of the paper is to identify factors which determine energy policy in the EU countries in the middle of 1990s. This objective is achieved in three stages. First, the changes in the distribution of RES in 26 EU countries in the period between 1995 and 2014 are investigated. The analysis demonstrates that over the last 20 years the EU countries diversify the RES they use, which results in substantial changes in their distribution. Second, the distribution of energy sources in 1995 is described, as it is assumed that the distribution might be a crucial factor influencing energy policy in each country. Third, several other factors related to energy security, environmental concerns, economy and politics are considered as potential determinants of renewable energy development.

Two statistical methods of variable selection, namely, the best subset regression and the LARS method, reveal that the present (in 2014) share of RES in the energy mix significantly depends on the condition of the EU countries in the middle of 1990s. The distribution of energy sources in 1995 is the crucial determinant of renewable energy development. Countries without their own fossil fuel sources are the ones which develop renewable energy to the greatest extent. Other important factors boosting RE development include: GDP per capita, concentration of energy supply (SWI), and the costs of consumption of energy obtained from fossil fuels in relation to GDP.

1. Introduction

Fossil fuels lay the foundation of energy balance in the European Union countries. Their share in the total primary energy supply (hereafter TPES) in 2014 amounted to 34.4% for oil, 21.4% for natural gas and 16.7% for coal. Nuclear energy constituted 14.1% of the TPES and renewable energy (hereafter RE) – 12.5%. In 2014 the TPES in the EU countries equalled to 1606 Mtoe, while net import constituted 54.8% of the TPES and increased in comparison with 1995, when it amounted to 44%. A growing dependence of the EU on imported energy coupled with diminishing deposits of its own resources and the necessity to provide energy at acceptable prices increase the role of energy security and energy policy.

The EU dependence on import of energy sources contributes to the growing interest in renewable energy sources (hereafter RES), which is reflected in introducing relevant directives in the area of energy policy. The first one, Directive 2001/77/EC [1], issued in 2001, requires each member state to take appropriate measures to achieve a specific indicative target for the consumption of electricity produced from RES. The global target was to reach the indicative share of gross national energy consumption (12%) with the 22% indicative share of electricity produced from RES by 2010. Another one, Directive 2003/30/EC [2], aimed at the promotion of the use of biofuels and other renewable fuels for transport (5.75% share of biofuels in the consumption of transport fuels). In accordance with Directive 2009/28/EC [3], the EU countries should increase the share of energy obtained from renewable sources in their overall energy consumption. European climate and energy package includes targets to be achieved by 2020: a 20% reduction in the EU greenhouse gas emissions below the 1990 levels, raising the share of the EU energy consumption produced from RES to 20%, and a 20% improvement in the EU's energy efficiency. Additionally, at least 10% of the final consumption of energy in transport should come from RES.

Specifying energy policy targets requires an insight into economic,

Abbreviations: TPES, Total primary energy supply; RE, Renewable energy; RES, Renewable energy sources; PCA, Principal component analysis; BSR, Best subset regression; AT, Austria; BE, Belgium; BG, Bulgaria; CY, Cyprus; CZ, Czech Republic; DE, Germany; DK, Denmark; EE, Estonia; ES, Spain; FI, Finland; FR, France; GR, Greece; HR, Croatia; HU, Hungary; IE, Ireland; IT, Italy; LT, Lithuania; LU, Luxembourg; LV, Latvia; MT, Malta; NL, Netherlands; PL, Poland; PT, Portugal; RO, Romania; SE, Sweden; SI, Slovenia; SK, Slovak Republic; UK, United Kingdom

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technical and geographical factors that both stimulate and hinder RE development. Painuly et al. [4] list several factors which should be taken into account while assessing development of RE: an adequate resource base for RES, available technologies and their costs, commercial viability and financing (public, private, international), environmental impact and benefits, socio-economic impact (including job creation), and coverage of both centralised and decentralised options. They distinguish techno-economic and economic factors and introduce six different types of the RES potential including theoretical, geographical, technical, techno-economic, economic and market potential. There are studies devoted to technical methods and tools of evaluating the potential of renewable energy sources (e.g. Izadyar et al. [5] present the review of these studies), but only several of them use statistical approaches to investigate the determinants of such development (e.g. [6–14]).

The aim of the study is to identify the main determinants of RE development in the EU countries, with emphasis on the impact of the distribution of energy sources in the middle of 1990s on RES in 2014.

The study covers 26 EU countries; Malta and Cyprus are excluded from the analysis, due to their almost non-existent share of RE in the TPES, and the fact that they import all energy sources they need. The share of RE in the TPES is selected as the dependent variable because, as stated by Aguirre and Ibikunle [9], firstly, policy targets are focused on achieving a certain share of energy from renewable sources in the energy mix, and, secondly, it is expected that RE will progressively displace more polluting energy sources in the energy mix.

The underlying assumption of the study states that RE development is a long-lasting process, and current RES development is a consequence of decisions made several years ago. It would be interesting to discover the reasons behind decisions that shaped energy policy in the past and their consequences which can be noticed at present. That is why, instead of using a panel model approach commonly employed in other studies (see, e.g. [6–15]), this study is based on cross-sectional regression. This empirical strategy, which includes different variable selection methods, is aimed at finding crucial determinants of RES and allows for analysing the impact of determinants related to environment, security of supply, economy, and politics.

Choosing the year 1995 as a reference point is dictated by the fact that it was the year in which the EU initiated legal procedures aimed at promoting RE development. That year the European Commission published *Green Paper* [16], which delineated the European Union energy policy and listed three basis targets connected with gas and electricity monopolies. That year also another official document, *White Paper. An Energy Policy for the European Union* [17], was issued by the Commission of the European Communities. It contained a detailed set of regulations within the area of energy policy and stated general frameworks of this policy in the EU countries (i.e. globalisation of energy markets, ecological problems, technology, institutional responsibility of the Community, etc.).

The study is divided into three main stages.

The objective of the first stage is to evaluate the changes in the distribution of RES in the period between 1995 and 2014. Principal component analysis (hereafter PCA) is used to describe the share of different RES in total RE. The comparison of the results obtained for 1995 and 2014 indicate which renewable sources gain in importance during the last 20 years. PCA also allows for describing RE development and identifying the direction of progress in this area, including progress resulting from technological advances.

The second stage of the study focuses on the distribution of energy sources, which seems a crucial factor in RE development. Several factors make it significant. Firstly, it is inextricably linked to national energy security, as most EU countries have to import energy sources (mainly oil and natural gas) from countries outside the EU, and only few EU countries have adequate domestic supplies of energy sources they need. Secondly, the share of energy sources in the energy mix in a given country exerts a direct influence on the natural environment, since using e.g. coal is connected with high emissions of pollutants, while using solar power is not. A high share of coal in the energy mix usually entails high employment in the mining industry, so a potential change in this area (i.e. reducing coal mining) will definitely entail socio-political consequences. Some researchers (see, e.g. [18,19]) support the hypothesis that strong lobbying has led to a strong position of traditional energy sources in both politics and economy. This lobbying of traditional energy industries can be noticed in the capital markets, in the military industry, and, in general, in the political decision-making process. Additionally, introducing changes in the distribution of energy sources is connected with high financial investments. As opposed to earlier studies [6–8,10,13,14,20], which consider only the shares of particular energy sources in the overall energy consumption, this study employs PCA.

The objective of the third stage is to identify the key determinants of RE development. The study takes into consideration a large set of potential variables in an attempt to follow the reasoning employed by policy makers. When they make decisions regarding the distribution of energy sources, they consider various factors including energy security, energy self-sufficiency, environmental costs, international treaties and commitments, political costs of potential changes in the structure of energy production, or the political power of interest groups, including miners. Together with four categories of potential determinants mentioned above, the impact of the distribution of energy sources in 1995 is investigated and described using PCA. In order to distinguish the key determinants of RE development, two statistical methods are employed: the best subset regression (hereafter BSR) and the lasso method [21].

The paper contributes to the literature in several aspects.

Firstly, it is based on the assumption that changes in the shares of energy sources in the energy mix require a relatively long period of time. The examples supporting this assumption include e.g. problems with investments in a nuclear power plant in Poland [22], the decision to shut down nuclear power plants by 2022 in Germany [23,24] and by 2034 in Switzerland [23], or the NCB's *New Strategy for Coal* in the UK, which was issued in 1985, and which is still the source of changes in the coal industry [25]. Thus, it seems reasonable to assume that the present distribution of energy sources, including the share of RES, is the net result of decisions made years ago. Making important strategic decisions in the past was based on the adequate assessment of energy security (including its uninterrupted availability), the need to match the strategy to the internal situation of a given country (including the labour market or budget capacity to invest in the energy sector), or the protection of the natural environment. The decision to choose a cross-sectional regression instead of a panel regression most frequently used in previous studies stems from the assumption that the distribution of energy sources is a long-lasting process.

Secondly, in order to explain the current level of RE development, the following determinants belonging to four categories describing the EU countries in the middle of 1990s were selected: the distribution of energy sources, economic conditions, energy security and climate protection. They are likely to have influenced the decisions affecting energy policy made at that period.

However, such a substantial set of variables poses a challenge to statistical procedures. They are often collinear, which renders the interpretation difficult and makes the estimation of parameters inefficient. In order to identify the determinants of RE development, it is necessary to limit the number of variables used in the study and to select only the ones which exert actual influence on this development. That is why, and this is the third novel aspect of the study, two methodological approaches rarely used before are employed, namely, the BSR and the lasso method [21]. The lasso method is considered the best method for variable selection, but, surprisingly, is not frequently used in energy economics studies.

Fourthly, the study considers the share of the main energy sources in the energy mix as the determinant of RE development and uses PCA to describe it, which is an approach not taken before. Such choice is

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