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Decomposing the changes in European final energy consumption

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ABSTRACT

The present paper aims at decomposing the rates of changes in final energy consumption in the European Union (EU) into the European, sectoral and competitive effect in the period 1998–2015. To that end, it uses dynamic shift-share analysis.

The results indicate the importance of all three effects. The European effect was most responsible for the changes in final energy consumption, particularly in the period marked by synergic influence of the financial, economic and energy crisis, while the sectoral and competitive effect influenced them more considerably in the remaining time period. The results also indicate that heterogeneity in the sectoral structure in energy consumption was low as well as sectoral concentration across EU states in the whole period considered.

1. Introduction

The European Union (EU) consists of the dynamic and changing national states which share certain similarities but which are also different with respect to their socio-economic, political, historical, geographical, climate and other features. It is plausible to expect that these differences have been translated to the usage of energy, whereby growth of or a decline in national or sectoral energy consumption may in turn more or less affect sustainable growth and development of the EU economy.

The relationship between energy use and economic growth has been extensively studied in the literature (for a review, see Refs. [1,2]). Thereby, it is recognized and supported by theory and data they are related to, although the direction of causality is not always the same [3]. This research interest has been motivated by increasing concern about the scarcity of natural resources such as energy availability and constraints on economic growth [4], particularly since the oil crises in the early 1970s (see e.g. [5,6]). If energy is scarce, it may impose constraints on economic growth and development [7], while technological advances cannot hinder them [3].

However, since energy consumption has adverse side effects such as anthropogenic greenhouse gas emissions [8] that degrade environmental quality, it can make the long-run growth unsustainable. Hence, since the 1990s, many researchers have started to investigate the relationship between environmental degradation or energy consumption and economic growth within the environmental Kuznets curve (EKC) (for a review, see Ref. [9]). The EKC hypothesizes an inverted U-shaped relationship between these variables. This indicates that environmental quality deteriorates at early stages of economic growth and subsequently improves at a later stage. The results of these studies did not support its validity in all considered cases. Nevertheless, many countries, including the whole EU, have been engaged in the mitigation of these emissions.

Recent findings for the EU show that there is a positive and statistically significant relationship between energy consumption and economic growth [10,11]. However, considering causality, they are mixed (see Ref. [3]). With respect to the EKC, the results are also inconclusive (e.g. [12,13]). The results differ depending on the sample structure, econometric methodology applied, the time period and the type of energy considered or model specification. They also differ due to different country characteristics such as different energy production and consumption patterns, sectoral composition, institutional arrangements, energy policies, etc. [2].

The present paper focuses on energy consumption following (*i*) the thesis that energy is indispensable in the creation of value added [14], and therefore an important driver of economic growth and development [1], (*ii*) the fact that energy consumption is responsible for approximately 80% of anthropogenic greenhouse gas emissions in the EU [15], and (*iii*) the efforts of the EU to have *smart, sustainable and inclusive growth* that is consistent with energy and environmental goals.

The EU has been committed to building the Energy Union which should facilitate the free flow of energy across borders and a secure, competitive and sustainable energy supply in every EU state [16]. Thereby, resolving grid issues and barriers for renewable energy development (see Ref. [17]) and reducing the demand for energy as well as improving energy efficiency were set as its important objectives. The targets set for 2020 and 2030 [18,19] include a significant cut in greenhouse gas emissions compared to 1990 levels (20% and 40%,

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respectively), an increase in the share of renewable energy consumption (at least 20% and 27%, respectively), and an improvement in energy efficiency (at least 20% and 27%, respectively). Several policy incentives, programs and measures were designed and implemented to achieve them (for a review, see Ref. [20]), and consequently, the EU as a whole has made considerable progress towards meeting them [21]. However, the results achieved are different across the EU member states due to the existing differences arising from a wide range of factors such as productive characteristics and a sectoral structure of the economy, efforts invested to increase energy efficiency or stance to pro-environmental behavior (see, e.g. [22–25]). Hence, it is important to know the changes in final energy consumption in the EU and factors responsible therefor to assess their developments within the context of the stated energy targets and policy design.

The main purpose of this paper is to decompose the changes in final energy consumption into three contributing components or effects, i.e., the European, sectoral and competitive effects in the period 1998–2015. The European effect measures by how much a growth in total final energy consumption in an individual EU state can be attributed to the overall growth rate in the EU economy. It indicates the expected change in final energy consumption in a country if it had changed at the same rate as the EU. The structural effect reflects the energy end-use structure of a given economy. The competitive effect compares an individual state's growth rate in an energy end-use sector with the growth rate for that same sector at the EU level. Hence, it reflects the unique factors specific to each EU member state departing its sector from what would be expected if it depended only on the EU evolution and sectoral composition.

Since the focus is on examining the growth of various energy end-use sectors of the EU member states, the paper also examines and discusses the features of and changes in sectoral composition. That may be helpful for analyzing the past trends and better understanding what could happen with the final energy consumption pattern in the near future assuming no significant changes in the existing circumstances.

To study changes in final energy consumption in the major energy end-use sectors, shift-share analysis is applied in the present paper due to its technical simplicity in application, non-demandingness and easy accessibility of data required for analysis, but well capturing the underlying changes in the considered variables and making the analysis fast and reasonably accurate [26,27]. Shift-share analysis belongs to decomposition techniques which have been applied in several other energy and environmental studies that cover the European territory (e.g. [23–25,28–31]). Though, the shift-share application in energy and environmental studies has received far less attention.

The shift-share method enables us to unveil whether and to what extent the European policy and economy might be responsible for changes in the variable of interest, and for example, which state's end-use energy sectors are growing or shrinking compared with the EU average. Bearing that in mind, it is more suitable than index decomposition techniques which have been widely applied in energy consumption studies (for an extensive survey on its application in energy and environmental economics, see Ref. [32]). They decompose the growth rates of the variable of interest (e.g., energy consumption or energy intensity) into its structural and efficiency components, whereby the former is related to sectoral changes.

The paper contributes to the field twofold. First, it evaluates the size of each effect over the study period. Second, it identifies the patterns of sectoral specialization and geographical dispersion in final energy consumption among member states and then assesses their stability over the period 1998–2015.

The remainder of the paper is organized as follows. Sections 2 and 3 provide a brief overview of the literature and portray the EU energy landscape with respect to final energy consumption, respectively. Section 4 briefly describes the shift-share method, while Section 5 presents and discusses the results of the final energy consumption decomposition. It also explores the evolution of end-use sector specialization and sectoral concentration. Section 6 concludes the paper.

2. Literature review

Since energy is commonly considered as indispensable for economic activity, it has long attracted research attention. Research efforts have been directed toward investigating a complex relationship between energy consumption, economic growth and/or environmental degradation (e.g. [2–4,9–13]). If energy is scarce or used inefficiently, it can constrain economic growth and development [5–7]. Moreover, since the use of energy has an adverse environmental impact [8,15], it can jeopardize their sustainability. It is important therefore to manage energy consumption effectively and efficiently, bearing in mind both its indispensability in the creation of value added and adverse effects on the environment.

As mentioned in the previous section, changes in energy consumption are caused by numerous factors such as a sectoral structure of the economy, weather conditions, efforts invested to increase energy efficiency or stance on pro-environmental behavior (see, e.g. [22–25]). Understanding the driving factors or effects behind energy consumption changes may shed light on consumption patterns and provide a basis for assessing their developments within the context of the stated energy targets and eventually better policy design.

To improve the understanding of the changes in the patterns of final energy consumption in the EU over the considered time period, the present paper aims to decompose final energy consumption. To that end, different decomposition techniques may be used such as index decomposition analysis, structural decomposition analysis and shift-share analysis. Li and Wang [33] pointed out that the former, which uses methodology based on index numbers, has been often applied by energy researchers to study the driving forces of energy use and energy-related emissions in a specific energy consumption sector. The latter may be used when input-output tables, which are based on large numbers and specific effects, are available to researchers. For a description of the index decomposition methods and comparisons with other methods, see Ang and Liu [34].

This paper applies shift-share analysis. Originally, it was created as a forecasting technique for regional growth, i.e., to analyze the extent to which the difference in growth between each region and the national average is a consequence of the region performing uniformly better than the average on all industries [35]. However, in the last two decades, it has also been used to decompose a variable of interest, mainly employment and value-added, at the cross-country level, the EU level, for example (e.g. [35–37]). Thereby, energy variable has also become a variable of interest for cross-country studies (e.g. Refs. [23–25,28–31,38]). Certainly, a comparison at the country level suppresses a great deal of geographical variance, as noticed by Melachroinos [39] But, at the same time, he stressed that such comparison may be fruitful since future-shaping policies cannot be made without a consensus of national governments.

However, only several studies have investigated dynamic changes related to energy and environment in European countries. They can be classified according to the level of aggregation into country-specific studies (e.g. [31]) and cross-country studies (e.g. [23–25,28–30]). The latter are briefly summarized below.

Cornillie and Fankhauser [28] decomposed energy data for Central and Eastern Europe and the former Soviet Union. They used the parametric Divisia method and found that structural change had moderate contribution to changes in overall energy intensity. Diakopulaki and Mandraka [22] examined industrial CO_2 emission trends for 14 EU countries in the period 1990–2003. Employing a refined Laspeyres model to determine the impact of several factors (output, energy intensity, structure, fuel mix and utility mix), they concluded that most EU countries have made a considerable but not always sufficient effort to decouple emissions from industrial growth. Additionally, they stressed that index decomposition analysis is better than input-output