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Multilevel LMDI decomposition of changes in aggregate energy consumption. A cross country analysis in the EU-27

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HIGHLIGHTS

- Increase in EU-27 aggregate energy consumption is decomposed through LMDI at 3 levels.
- We present the subgroup activity effect and we demonstrate its nulls consequences.
- Structural and intensity group effects lose influence when moving to a higher level.
- R&D, quality energies, efficient technologies, are main tools to lower energy consumption.
- Structural effect: "Green" attitudes and changes in consumer choices, also necessary.

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ABSTRACT

This paper aims at analysing the factors behind the change in aggregate energy consumption in the EU-27, also identifying differences between member states. The logarithmic-mean Divisia index method (LMDI) is applied to multiplicatively decompose, at the country level, the variation in aggregate energy consumption in the EU-27 member states for the 2001–2008 period. We also analyse the sensitivity of the results when several aggregation levels are considered, with energy intensity used as the criterion to aggregate countries. This allows us to check robustness of results, also enabling an improved understanding of both inter and intra-unit effects. Results indicate that improvements in energy efficiency in the EU-27 were not enough to overcome the pressure of European economic activity on aggregate energy consumption. Mediterranean countries, and especially former communist states, increased their energy consumptions, most of them favoured by structural change. The analysis also reveals that the impact of intra-group movements on aggregate energy consumption is partially offset when moving from higher to lower aggregation levels.

1. Introduction

The United Nations designated 2012 as the *Year of Sustainable Energy for All*. The significant role of energy in economic growth, as well as the need for urgent measures, were also recognised at the Rio20Summit (2012). The EU-27 itself has become increasingly dependent on energy imported from Non-EU Member States, thus creating – among others – political, social and economic risks for the Union. In year 2009, the high dependence on energy imports, as well as the shrinkage of traditional energy resources – added to insufficient expansion of renewable resources and concerns on greenhouse gas emissions and climate change – led EU authorities to design a European energy policy. The main objectives of this policy are: (1) reduction of dependence on imports, (2) security of supply, and (3) sustainable development. A number of actions are put into operation, including: Intelligent Energy for Europe 2003–2006 (a multi-annual programme for action in the field of energy), Action Plans for energy efficiency 2000–2006 and 2007–2013 (including measures to reduce energy consumption and improve energy efficiency), and the Green Paper on Energy Efficiency 2005 (aimed at relaunching energy saving). In this agreement, the Member States commit themselves to reduce energy consumption by 20% for 2020[1] (compared to energy consumption forecasts for that year). This undertaking also encouraged the signing of an international agreement that obliges developed countries to reduce their greenhouse gas emissions by 30% – compared with 1990 levels – for year 2020.

Although the EU as a whole is one of the biggest energy consumers and polluters, and despite their considerable concern on this issue, there are no decomposition studies available that

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[1] This is a European initiative published by the European Commission (2005) in its Green Paper.

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explore the change in aggregate energy consumption (AEC) with a view to analysing its driving forces. Many empirical studies addressing this objective refer to APEC countries (Ma and Stern, 2008; Liao and Wei, 2010; Sahu and Narayanan, 2010; Chung et al., 2011; Shahiduzzaman and Alam, 2012; Xu et al., 2012; Zhang and Guo, 2013). In this paper we deal with decomposing the change in aggregate energy consumption between two benchmark years, for each of the 27 European Member States. Our study aims at identifying and analysing the influence of the specific factors underlying that change at the macroeconomic level.

Instead of using alternative approaches, such as Structural Decomposition Analysis (SDA) and econometric analysis, we shall rely on Index Decomposition Analysis (IDA). This technique imposes milder requirements in terms of data availability (this being particularly useful in international studies), as well as using sector level data and allowing for multiplicative decompositions. Relying on IDA, we multiplicatively decompose the variation of the aggregate into the contributions from several determinant factors, namely, activity, structural and intensity. Said otherwise, we will apply a so-called energy consumption approach (Ang and Lee, 1994).

The activity effect measures the impact that changes in overall activity level have on energy consumption, whereas the structural effect involves variations in energy consumption as a consequence of changes in the sectoral (resp., regional) production structure. The intensity effect relates to changes in both sectoral (resp., regional) activity mix and sectoral (resp., regional) energy intensities. The above analysis will allow us (1) to understand the behaviour patterns of the aggregate and its driving forces and (2) to derive action lines in order to achieve a reduction in energy consumption.

On the other hand, a large proportion of prior studies have focused on a single, fixed aggregation level. This is particularly evident in international studies, where data collection at several aggregation levels often becomes an issue. Nevertheless, it is well known that a given methodology may lead to different final results depending on the aggregation level specified by the researcher. In this regard, a sensitivity analysis of how results are affected by a specific aggregation level becomes important in order to check the robustness of results. In this paper we shall carry out a decomposition analysis at three different aggregation levels. This will allow us to properly assess the effects of disaggregation. In addition, application of a specific aggregation criterion can enable more accurate measurement of some specific aspects, also allowing for isolation and control of others.

The highest level includes the 27 EU countries, whereas in the medium one EU states are grouped into 8 spatial units. Only three regions are considered in the lowest level. These levels are constructed with a view to composing homogeneous groups in terms of energy intensity. This aims at checking whether, after controlling for the energy intensity factor, there still exists a significant impact of the geographical differences in production structure and market size.

Afterwards, returning to the country level decomposition, we will analyse each country, comparing results and deriving a number of strategies and policy implications in order to achieve reductions in energy consumption.

Summing up, the objectives of the paper are threefold: (a) identification, quantification and explanation of the driving forces behind the change in aggregate energy consumption, (b) analysis of the findings at several regional levels, and (c) comparative analysis of results across countries. Our findings will be helpful in order to understand how the aggregate is affected by a number of driving forces, also allowing us to design strategies and policy recommendations to reduce aggregate energy consumption in these countries. This will favour energy saving, cost reductions, competitiveness of these regions, increased exports, higher growth rates and, in another order of things, fulfilment of international agreements and being part of a sustainable growth.

In Section 2 we outline the LMDI-based methodology for multiplicatively decomposing the change in aggregate energy consumption into the contributions from the activity, structural and intensity factors. More precisely, Section 2.1. briefly reviews single-period (*periodwise*) and time series decompositions, while Section 2.2. focuses on multilevel decompositions.

Section 3 reports an application of the above methodology in order to study AEC changes in the 27 European member states in the 2001–2008 period. We begin by deriving decomposition results for the three aggregation levels considered. Thereafter, we will try to detect any differences in the results that may be explained by so-called subgroup effects. Then, focusing on the decomposition results at the country level, a comparative analysis across member states is carried out.

In Section 4 we review the political actions adopted by the European Union in order to reduce European energy consumption. The effectiveness of these measures is also discussed in the light of the results presented in the previous section.

Finally, we draw some conclusions. We find that overall EU-27 aggregate energy consumption increased by 2.245% between 2001 and 2008, pushed up by the influence of inter-regional structural changes, and particularly by the inertia of overall production. This increase took place in spite of improvements in energy efficiency in the same period.

2. LMDI-based decomposition analysis

A large number of decomposition techniques is now available in the energy and environmental literature. Among them, Index Decomposition Analysis (IDA) is widely used in both energy and environmental economics, for the analysis of energy consumption and emissions. Methodological and practical aspects of this technique have been studied by Jenne and Cattell (1983), Reitler et al. (1987), Boyd et al. (1987), Liu et al. (1992a), Ang and Lee (1994), Ang (1995a), Ang and Choi (1997), Sun (1998) and Albrecht et al. (2002), among others. Numerous specific methods exist, ranging from those based on classical Laspeyres (Liu et al., 1992b; Unander, 2007), Paasche and Marshall-Edgeworth indices (Boyd and Roop, 2004) to extended and refined models (Ang and Choi, 1997; Sun, 1998; Fernández and Fernández, 2008).

We will focus on the logarithmic mean Divisia index (LMDI) method introduced by Ang and Choi (1997). According to Ang (2004, 2005), multiplicative LMDI is the preferred index decomposition method, from both theoretical and applied perspectives[2].

2.1. The energy consumption approach

We begin by considering the following variables in period t:

E_t	Aggregate energy consumption.
$E_{j,t}$	Energy consumption in region j.
Y_t	Total production.
$Y_{j,t}$	Production of region j.

[2] From a theoretical standpoint, LMDI provides exhaustive decompositions (i.e., decompositions with no deviations from the target values). It also fulfills the time and factor reversal tests, as well as being able to handle zero values and being applicable when several levels of disaggregation are available (Ang, 2004). From a practical perspective, a direct relationship exists between additive and multiplicative decompositions – this equivalence is helpful when interpreting results – , and the expressions for the effects have the same mathematical forms irrespective of the number of factors considered – this being useful in order to implement the method in applications.