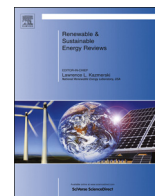




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Driving forces for aggregate energy consumption: A cross-country approach

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ABSTRACT

Although a cornerstone for development, past and current energy use has often posed a major challenge for policymakers with respect to planning and management. Within this context, in this paper an updated multi-sectorial cross-country assessment of energy consumption trends was undertaken, aiming at identifying the main drivers of changes in aggregate energy consumption. These drivers have been interpreted in the light of the policy measures that have been implemented over the years by different countries to achieve a sustainable development of the energy sector. The cross-country assessment encompasses a set of developed (United Kingdom, Portugal and Spain) and emerging (Brazil, China, and India) countries. Resorting to the Logarithmic Mean Divisia Index (LMDI) decomposition method, changes in the aggregate energy consumption were decomposed into three main explanatory effects: activity, structure and intensity. The major findings achieved reflect the relevance of intensity and activity effects in detriment of the structural effect. The assessment of energy consumption trends using the LMDI decomposition method provides critical information regarding which is the dominant factor that should be focused in policy design.

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1. Introduction

Although a cornerstone for development, past and current energy use has often contributed to an imbalance of socio-economic and environmental dimensions of sustainability. This

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resulted in a significant challenge for policymakers with respect to energy planning and management. As the multi-dimensional implications of unsustainable use of energy become further exposed [1], the need to develop and promote policies, which reinforce resource and 'eco-economic' decoupling [2,3], while fostering environmental improvements, become relevant. In this context, alternatives, such as the improvement of energy efficiency and the incorporation of renewable energy sources (RES) in a country's energy system, have become increasingly used both at national and international levels. In fact, the need to make this transition in order to avoid risks for both human and natural ecosystems prompted by climate change has been emphasised by [4]. The role and relevance of RES in different countries has experienced a significant growth, driven by such concerns. The rapid evolution and significant contribution of various renewable technologies for the fulfilment of targets either at national and/or international level has been reported for developed and emerging countries. Technical and policy aspects of wind power integration in Ireland and United Kingdom have been reviewed by [5,6]. Within European Union's (EU's) policy framework for RES, progress of the contribution of renewable energy alternatives for energy supply has been assessed by [7,8]. Contribution of RES initiatives for the energy sector were also reviewed in the context of the national action plan on climate change for India [9]. Technical, political and social aspects were also taken into consideration to assess the increase in integration of wind power in the Brazilian energy matrix [10]. The contribution of wind power sector and its environmental benefits for the energy sector in China, has been assessed by [11].

The multidimensional benefits of these alternatives contribute to conciliate conflicting interactions between energy and socio-economic and environmental dimensions, as emphasised by [11] within a country, and [12,13] on a cross-country context. Therefore, assessment of energy and energy-related issues are extremely relevant, within policy decision-making context, to ensure future sustainability. This view is increasingly recognised through multiplicity of international initiatives undertaken, such as Millennium Development Goals.¹

Within this context, in this article an updated (1990–2012) multi-sectorial cross-country assessment of energy consumption trends was undertaken, aiming at identifying the main drivers of changes in aggregate energy consumption. These drivers have been interpreted in the light of the policy measures that have been implemented over the years by different countries to achieve a sustainable development of the energy sector. It was evaluated if overall trends are consistent with or reflective of countries' policy efforts regarding climate change impacts. Additionally, this approach could be indicative of which effects should be focused to further contribute in terms of policy efforts towards the sustainable development of the energy sector. This cross-country assessment encompasses a set of developed and emerging countries, with United Kingdom, Spain and Portugal representing the former and Brazil, China and India representing the latter. Energy is a focal point of many of the challenges currently faced by countries in spite of their developmental stages. This set of countries is characterised by substantially different energy mixes, socioeconomic backgrounds and commitment towards energy sustainability challenges. In fact, several authors (e.g. [14,15]) have emphasised close interconnection between economy, energy production and use, and emission growth patterns in different countries. Therefore, in order to support the need to further address these inter-

linkages, it is relevant to focus on countries at different stages of development. Additionally, the relevance and adequacy of the reduction of energy consumption and related emissions have also been renewed in the context of reaching a new global climate agreement.

Cross-country data comparability has been ensured by resorting to a consistent dataset from the International Energy Agency (IEA) for energy consumption by sector (e.g. industry, transports, commercial and public services, and agriculture, forestry and fishing sector) and National Accounts Main Aggregate Database (UNStats) for economic data (e.g. country GDP and sectorial Value Added). Changes in sectorial energy consumption were assessed resorting to an Index Decomposition Analysis (IDA) approach based on the multiplicative Log Mean Divisia Index (LMDI) decomposition method. This approach enabled the disaggregation of changes in energy consumption into three main drivers (activity, structure and intensity). Overall, the results obtained reflected the relevance of intensity effect regarding aggregate energy consumption, since, for all countries, main variations have been associated with both overall activity and intensity effect, in detriment of structural effect.

The remainder of the paper is organised as follows. Section 2 presents a brief overview of the literature regarding energy consumption decomposition analysis. Section 3 describes the methodological approach adopted in the present study. Section 4 presents a brief overview of the main trends regarding energy and economy nexus for the six countries included in this study, measured through changes in energy consumption and energy intensity levels. In Section 5, the results from the application of the multiplicative LMDI decomposition approach are presented, followed by a discussion of those results. Finally, Section 6 draws the main conclusions of the paper and presents avenues for future research.

2. Literature review

Emergence and subsequent developments of Index Decomposition Analysis (IDA) have been interlinked and shaped (either directly or indirectly) by the energy concept. Energy related issues, namely energy efficiency and, to a certain extent, energy security, have been the primary focus of studies since the 1980s [16]. However, after 1990, with the increasing recognition of the climate change impacts, IDA has extended its scope to environmental aspects of energy production and use, particularly energy-related CO₂ emissions [16,17]. Yet, due to the primary energy's high carbon content and increasing global consumption rate, the energy sector has been considered crucial to address climate change [18]. Therefore, although IDA's initial and direct focus has shifted from energy consumption to energy-related emissions, the assessment of its drivers is still extremely relevant for policy design and evaluation. This interconnection is patent in the following literature sample (see Table 1), addressing recent studies at country level (often from a sectorial approach) and/or cross-country level (contemplating both developed and emerging countries).

These studies are often reflective of areas that are increasingly relevant regarding energy consumption and energy-related emissions. For instance, increases in energy consumption and energy-related CO₂ emissions in the Chinese industry sector have been identified by [19,21]. Resorting to the LMDI method for a period between 1991 and 2010, it was possible, for both authors, to identify the activity effect as the main driver for emission increase, being offset by energy intensity and a shift towards a cleaner energy mix effects. The increase in the consumption of RES and the promotion of cogeneration were also some of the policy implications suggested by [20], in order to promote energy and carbon

¹ United Nation Millennium Development Goals consist of a global alliance to achieve a total of eight goals, associated with the eradication of extreme poverty [63]. Access to energy has been considered crucial to achieve these targets [64].

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