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Ordinary and Special Regimes of electricity generation in Spain: How they interact with economic activity☆

António Cardoso Marques[a,*], José Alberto Fuinhas[a], Sónia Almeida Neves[b]

[a] NECE-UBI, University of Beira Interior, Management and Economics Department, Portugal
[b] University of Beira Interior, Rua Marquês d'Ávila e Bolama, 6201-001 Covilhã, Portugal

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ABSTRACT

The purpose of this paper is to review the literature focused on the energy/electricity-growth nexus, highlighting how the focus has shifted from aggregated energy/electricity consumption towards specific energy sources. Moreover, it aims to shed light on the relationships between different energy/electricity sources and economic growth. Empirically, the paper focuses on the analysis of interactions between electricity generation in Spain under both the Special Regime (*SR*) and the Ordinary Regime (*OR*), and their relationship with economic activity. Data for Spain is studied for a time span from January 2003 to January 2016. The Toda-Yamamoto causality test is carried out to check for causality relationships. Additionally, both short- and long-run effects are assessed by using the ARDL bounds test approach. Overall, the results reveal high internal consistency when comparing the ARDL results with the causality analysis. The substitution effect was detected between OR and SR. However, the negative effect of the SR on economic activity deserves special attention by energy policymakers. This paper argues that the main challenge of renewable sources for policymakers is their cost-effectiveness.

1. Introduction

There is an ongoing worldwide trend towards diversification of sources within the national mixes of the electricity generation. The increased need for greater penetration of renewable energy has prompted countries to design frameworks that allow renewable and conventional sources to coexist. Regarding the countries of the Iberian Peninsula, Portugal, and Spain, the electricity generation systems are organized into two generation regimes: the Ordinary Regime (OR), and the Special Regime[1] (SR). Broadly speaking, the OR includes nuclear, coal, combined cycle, oil, gas and large hydro sources. In contrast, the SR comprises wind, solar photovoltaic (solar PV), solar thermal, biomass, cogeneration, mini-hydro sources and biomass/waste. These countries are among the leaders in the deployment of renewables, mainly wind power and solar PV to meet the objectives proposed by the EU in *directive 2009/28CE* [1]. However, this worldwide trend of diversification has been raising new questions not only for Transmission System Operators (TSO) but also for economies as a whole. Indeed, concerns about how to accommodate diverse sources within a national electricity system, and even the potentially differing effects of these sources on economic growth, have increasingly captured the attention of policymakers.

The energy consumption and economic growth nexus (hereafter referred to as the energy-growth nexus) has been a hot research topic in recent literature. Over time, energy-growth nexus studies have shifted their focus to individual energy sources instead of aggregated energy sources, creating new frameworks such as the electricity-growth nexus, nuclear-growth nexus, renewable-growth nexus and non-renewable growth nexus. A summary of the literature focused on traditional and new approaches can be found, for instance in Payne [2], in Ozturk [3], in Omri [4] and Tiba and Omri [5]. In fact, there is no consensus in the scientific community about the relationships between energy/

Abbreviations: ADF, Augmented Dickey-Fuller; ARDL, Autoregressive Distributed Lag; DOLS, Industrial Production Index; DSM, Demand-Side Management; ECM, Error Correction Model; EU, European Union; FMOLS, Fully Modified Ordinary Least Squares; GDP, Gross Domestic Product; GMM, Generalised Method of Moments; IPI, Industrial Production Index; KPSS, Kwiatkowski Phillips Schmidt Shin; N-RES, Non-Renewable Energy Sources; OECD, Organisation for Economic Co-operation and Development; OR, Ordinary Regime; PMG, Pooled Mean Group; PP, Phillips-Perron; PUMP, Pumping; PV, Solar Photovoltaic; RXI, Rate of coverage of imports by exports; RES, Renewable Energy Sources; SR, Special Regime; TSO, Transmission System Operator; VAR, Vector Autoregressive; VECM, Vector Error Correction Model

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* Corresponding author.
E-mail addresses: amarques@ubi.pt, acardosomarques@gmail.com (A.C. Marques).

[1] In the Spanish electricity system, the name "Special Regime" was abolished in 2014. After that, the electricity sources previously classified as Special Regime became classified under the "specific remuneration regime". In this paper, we opt to use the name "Special Regime".

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electricity consumption and economic growth. This lack of consensus could be attributed to the different databases, countries, variables selected and methodological approaches followed [2–5]. Consequently, to resolve these contradictory results, the aforementioned authors suggest that future research should include new approaches and methods [3], search for the existence of structural breaks, identify the signs of relationships [2] and increase the data frequency [4].

The objective of this paper is twofold. Firstly, this study aims to provide a survey of the literature focused on the energy/electricity growth nexus. Moreover, this survey will give special attention to the interactions between different energy/electricity sources and their impacts on economic growth. Secondly, this paper aims study the electricity system of Peninsular Spain, by analysing the relationship between economic activity and electricity generation from both OR and SR. Thus, this paper contributes to the existing literature in several ways. Firstly, it extensively reviews the literature focused on the interactions between different energy/electricity sources, and their relationship with economic growth, specifically focusing on the latest advances and findings. Secondly, an empirical analysis of the energy-growth nexus for Spain is added to the review. Empirical evidence of the nexus is scarce, (with some exceptions [6,7]), and the interactions between OR, SR and economic growth remain unexplored. Thirdly, the empirical analysis enables both the causalities and the signs of the relationships to be investigated using high data frequency, and the existence of structural breaks in the unit root process to be studied, as recommended in the literature [2–5]. In summary, this paper aims to look for answers to two main questions, namely: (i) how do the ordinary and Special Regimes interact? and, (ii) what are the consequences of diversification in the electricity mix on economic growth? In this way, the study is not centred on the traditional framework of the electricity-growth nexus, although a comparison with those studies could be possible. It should be mentioned that the traditional measure of economic growth, the Gross Domestic Product (GDP), is unavailable in a monthly frequency and, as such, the Industrial Production Index (IPI) was used as an economic growth proxy.

Regarding the empirical analysis, the study uses monthly data from January 2003 to January 2016, applying the ARDL (Autoregressive Distributed Lag) bounds test approach [8] jointly with several procedures to check robustness, such as the Toda-Yamamoto [9] causality test. On the one hand, the existence of the variables I(0), I(1) and borderline, makes the methodological approach appropriate. On the other hand, the use of the ARDL allow us to capture the short- and long-run effects, separately, as well as the sign of the relationships, as suggested by Payne [2]. Overall, the results show a substitution effect between the two regimes. Regarding the effect of electricity generation on growth, the regimes under study exhibit quite different results. In fact, the Ordinary Regime drives economic activity, while, at the same time, the Special Regime hampers economic activity.

This paper is set out as follows. Section 2 provides an extensive review of the evolution of the energy-growth nexus. An overview of the Spanish electricity system is presented in Section 3. Section 4 is dedicated to the data and the methodology. The results are revealed in Section 5. Section 6 discusses the results, as well as providing recommendations for policymakers. Finally, Section 7 presents the conclusions.

2. Literature review – an update of the evolution of the energy-growth nexus

In energy economics, the relationship between energy consumption and economic growth has been a hot research topic in the literature. In fact, energy consumption is a critical variable for explaining economic growth [10]. However, the direction of these relationships have not been consensual in the literature [2–5]. Overall, four main hypotheses were defined to explain the causality relationships between the variables, namely: (i) *Growth hypothesis* – energy consumption incentivizes economic growth, i.e. there is a unidirectional causality running from energy consumption to economic growth [11,12]; (ii) *Conservation hypothesis* – economic growth stimulates energy consumption, i.e. there is a unidirectional causality running from economic growth to energy consumption [13,14]; (iii) *Feedback hypothesis* – energy consumption encourages economic growth and vice-versa, i.e. there is a bidirectional causality between energy consumption and economic growth [15,16]; and (iv) *Neutrality hypothesis* – energy consumption has no effect on economic growth, nor does economic growth incentivize energy consumption, i.e. there is no causal relationship between energy consumption and economic growth [17,18].

The analysis of the relationships between energy consumption and economic growth has evolved in the literature. The evolution is ongoing, moving from a perspective of aggregate consumption, usually primary energy consumption, towards electricity consumption and energy by source. More recently, the literature has attempted to go further in analysing the complexity of this relationship by examining the traditional relationship within the dynamics of the interaction between the various sources in the electricity mix. The remainder of this section is dedicated to reviewing that literature.

2.1. From the energy-growth nexus to the electricity-growth nexus

The work of Kraft and Kraft [19] in the 1970s, is a milestone in the analysis of the relationship between energy consumption and economic growth. Since then, the energy-growth nexus has been the focus of numerous papers, and most of them have tested the relationship empirically. Several papers focus on specific countries by using time series techniques [20,21], or on multiple countries through panel data analysis [22,23]. A survey of the main studies on the energy-growth nexus can be found in Ozturk [3]. Later on, this paper lists some weaknesses of the existing literature, and specifically, highlights the need to use both new approaches and multivariate models, as well as to test new variables with different characteristics under a kind of extended nexus for different countries and/or time periods.

Nowadays there is a trend to incorporate an environmental component in the energy-growth nexus [24,25]. Accordingly, the literature supports the argument that pollution must be taken into account when the energy-growth nexus is analysed, because it is essential for formulating policies to achieve sustainable development [26]. Regarding methodological approaches, on the one hand, VAR/VECM Granger causality is applied to analyse the causalities between the variables in both time series analysis [21] and panel data analysis [27]. On the other hand, some studies have been conducted to obtain both causalities and impacts through Granger causality and an ARDL approach, respectively [25].

The trend of electrifying economies has brought increased pressure to refocus analysis on the role played by electricity in the nexus. Accordingly, the traditional energy-growth nexus has been reoriented to draw attention to electricity consumption, formulating a new nexus, named the electricity-growth nexus. As in the energy-growth nexus, both specific-country [28–35] and multi-country analysis is used [36,37]. A survey on the conclusions of the electricity-growth nexus can be found in Payne [2], as well as suggestions for future research on the electricity-growth nexus, such as examining the sign of relationships, reducing the omitted variables bias, and including the unit root process with structural breaks.

Subsequently, studies of the electricity-growth nexus at aggregate level were scarce. The analyses of the interaction between electricity consumption and economic growth for Bangladesh, confirmed the growth hypothesis in the short-run, and the feedback hypothesis in the long-run, using VECM Granger causality [35]. For the Gulf Cooperation Council countries, the feedback hypothesis was also confirmed by analysing the relationship between energy consumption and economic growth [38]. In contrast, Abbas and Choudhury [34] found a unidirectional causality running from economic growth to electricity