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The role of Portuguese electricity generation regimes and industrial production [☆]



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ABSTRACT

This paper examines how renewables (special regime) simultaneously interact with conventional sources (ordinary regime), within the Portuguese electricity generation system. There is also an appraisal of the relationship between these two regimes and economic activity, using the industrial production index. First difference VAR modelling was applied for monthly data for the time span of 2007:M1 to 2012:M10. The appropriateness of the VAR is proved. The relationship between variables develops within a structure of endogeneity, i.e., they generate feedback and may be both *explained* and *explaining* variables, simultaneously. The outcomes show a strong complementarity between the ordinary and special regimes. Economic activity causes electricity consumption but only the special regime causes economic activity. Moreover, the non-renewable component of the special regime does not cause a need for backup from either the ordinary regime or imports, contributing to a reduction in energy dependency.

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1. Introduction

Fostering renewable energy sources within a strategy of combating climate change, increasing energy efficiency and reducing energy dependence, has led some countries to create a dual organizational framework for their own electricity generating systems. Two regimes have arisen: ordinary and special. Roughly speaking, the former consists of traditional generation sources, while the special

regime includes new technologies taking advantage of renewable sources as well as joint use of both sources to produce both heat and electricity. On the Iberian Peninsula, this dual system is already in operation. Portugal and Spain have warranted particular interest in literature. Indeed, both have drawn up ambitious strategies to rebuild the framework of their electricity generation in order to accommodate heavy investment in alternative sources of generation.

The motivation for this research is twofold. On the one hand, electricity generation systems have had to accommodate increasing contributions from renewable sources introduced not only by choice, but also to meet international agreements. On the other hand, conventional sources, namely fossil fuels, have seen their share in the generation mix diminish, as seen in Portugal since the dual regime was implemented. Consequently we are motivated to seek to understand the consequences of this new mix of sources in the dynamics of economic activity. Thus, this research has three main objectives. First, to understand how renewables interact simultaneously with conventional sources in the Portuguese power generation system; second, to comprehend the role that the system's management variables, such as imports, are playing in the overall balance of the electricity system; and third, to appraise the relationship between economic activity and this dual system of electricity generation.

From the analysis of the literature looking at different sources of electricity generation, at first glance there is good reason to suspect that they interact with each other. Consequently, since the dual electricity generation scheme uses several energy sources, then it is highly probable that they interact as a system, not only between themselves, but also with other external variables, such as economic activity. In other words, the variables have feedback, which is a potential source of endogeneity among generation sources. Indeed, the variables could be explaining and explained variables, simultaneously. The availability of resources under the special regime could explain the use of conventional sources, but at the same time, the conventional sources could also explain the installed capacity of renewables. As such, an appropriate econometric technique is required to deal with this complexity. Accordingly, the analysis of the relationship between the ordinary/special regime and industrial activity in Portugal is pursued by modelling a Vector Autoregressive (VAR). The frequency of the data is monthly and the time span is 2007:M1 to 2012:M10. This analysis is now feasible since the data capable of supporting a robust analysis has become available. Furthermore, the monthly frequency has the advantage of eliminating most of the noise associated with high frequency data. At the same time it has the advantage of maintaining the relationship of endogeneity.

Overall the presence of endogeneity is proven and the results are robust. Electricity generated under the special regime is Granger-causing economic activity, in contrast to the ordinary regime. Within the special regime, both renewable and non-renewable components cause economic activity. For renewable components, results confirm the expected need for backup power, while the non-renewable components cause neither electricity generation under the ordinary regime nor even electricity imports. These findings are crucial aids in the process of making decisions about the deployment of renewables in combating climate changes, achieving energy efficiency and reducing energy dependence.

This paper is set out as follows: Section 2 presents a literature review and Section 3 is dedicated to an overview of the dual system of electricity generation in Portugal. Section 4 shows both the data and the preliminary empirical results and the model. The results are outlined in Section 5 and their robustness is checked in Section 6. Section 7 is concerned with the discussion of the findings and the paper concludes with Section 8.

2. Literature review

There is scant literature focusing on the relationship between electricity generation regimes, their interaction, and economic activity. Indeed, the overall tendency is to focus on analysis of the relationship between energy consumption and economic growth, which is known as the energy-growth nexus (e.g. [1,2]). Despite the vast amount of literature focusing on this nexus (e.g. [3]), no consensus on results has been achieved. Ewing et al. [4] gave some possible explanations for this *status quo*, namely the different economic structures of the countries, their level of development and even the particularities of the data used. The literature keeps trying to verify the presence of four known hypotheses in the energy growth nexus, namely: growth, conservation, feedback and neutrality (e.g. [5]). On the whole, the literature has used aggregated data, which does not allow the specific effect of each power source to be isolated. Some exceptions are Pao and Fu [6], Ewing et al. [4] and Sari et al. [7] who worked with disaggregated energy consumption per source. Ocal and Aslan [8] and Al-mulali et al. [9] examine the relationship between renewable energy consumption and economic growth. The first of these authors focus on Turkey and the latter control that relationship for countries' income levels.

Despite research on electricity and growth also being abundant (e.g. [10]), the relationship has been less studied for electricity derived from both renewable and conventional sources. This oversight should be quickly rectified, in view of the ongoing debate regarding the simultaneous accommodation of multiple generation sources within national electricity generation systems. These sources are intermittent renewables and predictable fossil fuels. To the best of our knowledge, study of the dynamics of adjustment between several energy sources within an electricity generation system is very scarce. Marques et al. [11] studied this interaction in Greece. They found that electricity generation from wind and solar photovoltaic causes generation from fossil sources, but not the opposite. At the same time, economic growth is caused only by conventional fossil sources, and not by renewable electricity. Al-mulali et al. [12] focus on a panel of 18 Latin American countries, to study the effect of both renewable and non-renewable electricity consumption on economic growth. They were not evaluating the interactions between sources, but they found that renewable electricity production was more significant than non-renewable production in promoting growth.

The growing simultaneous use of several electricity sources has led some countries to establish frameworks enabling the accommodation of renewables. In particular, for countries such as Spain and Portugal, a framework with a dual system of electricity generation has been set up. For Spain, Ciarreta et al. [13] show production and remuneration within the ordinary and special regime, with reference to Spanish legislation. They also appraise the installed capacity and the electricity generated from these two regimes. Also for Spain, Cossent et al. [14] focus predominantly on describing the support mechanism components of the special regime, either through feed-in-tariffs (FIT) or through a feed-in-premium (FIP), aimed at compensating the sale of electricity at market price. According to the first of these authors, the integration of *distributed generation—renewable energy sources*, which comprise the special regime, has been possible and desirable for Spain. Nevertheless, they stressed that this has happened in a setting of moderate growth in electricity demand and low interconnection capacity with neighbouring electricity generating systems. In fact, it seems that transactions in the international electricity markets there have not yet played a crucial role in the management of new generation technologies, namely renewables, in order to encourage more rationality in the installed capacity. Apart from further integration in neighbouring electricity markets,

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