



The effect of income on the energy mix: Are democracies more sustainable?

Esmeralda A. Ramalho^{a,1}, Tiago Neves Sequeira^{b,2,*}, Marcelo Serra Santos^{b,2}

^a ISEG, Univ. Lisboa and CEMAPRE, Rua do Quelhas, 6, 1200-781 Lisboa, Portugal

^b Departamento de Gestão e Economia and CEFAGE-UBI, Universidade da Beira Interior, Avenida Marques d'Avila e Bolama, 6200-001 Covilhã, Portugal



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ABSTRACT

This paper shows that the effect of income on the energy mix depends on the democracy level. We find that more democratic countries tend to depart from the hydroelectric power, oil, and geothermal sources of energy to rely on coal, natural gas, and modern renewable sources (nuclear, biomass, wind, and others). Less democratic countries tend to become more dependent on oil and natural gas with their own development. Moreover, the energy ladder transition from hydroelectric sources to natural gas appears to be escalated more quickly for less democratic countries. These transitions are thus more environmental friendly for more democratic countries than for less democratic ones. An extended multinomial fractional regression model is proposed to test and deal with the endogeneity of income.

1. Introduction

Electricity consumption rises with income. For simplicity we use a narrow concept of development using income as a proxy (see e.g. Csereklyei et al. (2016) for a detailed article on the relationship between energy intensity and income.) Furthermore, development usually carries out a transition of the major energy sources in the economy. The type of energy sources determine the ecological effect of such a transition. Specifically, low-income countries have electricity sectors dominated by hydroelectricity and oil-driven electricity generation, while high-income countries have more diversified electricity sectors that are more reliant on coal, natural gas, and nuclear power, as well as on the recent adoption of modern renewable sources such as wind power. This evolution of the energy mix (i.e. the bundle of resources used in generating electricity and thus its ecological effects) driven by development is usually called the “energy ladder” (e.g. Burke, 2010). For example, Andreas et al. (2017) studied the European countries energy transition through the “energy ladder” during the crises and concluded that that wealthy states show a strong progress in renewable energy transitions and invalidated the hypothesis according to which less wealthy states are too poor to be green. Another paper focusing on

the relationship between energy use patterns and development, Henriques and Kander (2010), concluded that the environmental relief – measured by energy intensity – obtained by the transition to a services economy is negligible.

Development may be related with the country's level of democratization, and this factor may be considered a possible determinant of the course of energy transition. This relationship may be explained by the incentives and institutions that democratic countries put forth which determine both the level of accumulation of production factors (namely human capital) and technological development (see e.g. Tavares and Wacziarg, 2001 and Sequeira, 2017 for articles that explore the relationship between democracy and development). Therefore, democratization emerges as a relevant determinant to be included in models that seek to explain energy mix, not only because its omission may cause the inconsistency of the estimators proposed, but also because its effect on the energy mix is an interesting issue that remains to be investigated. The intuition behind this relationship may be explained as follows. More democratic countries face constraints on the preferences of voters that autocracies do not face. Because of that, they can be more prone to invest in energies' resources that are preferred by consumers and firms. Also, because of voters' (and lobbies) preferences they may

* Corresponding author.

E-mail addresses: eramalho@iseg.ulisboa.pt (E.A. Ramalho), sequeira@ubi.pt (T.N. Sequeira), mssantos@ubi.pt (M.S. Santos).

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be unable to promote fast shifts between technologies linked to energies' production, even though they share the same income growth. These are the main issues that this article aims to shed light on.

Our contribution is twofold. First, one of the goals of this paper is precisely investigating if democratization influences and/or changes the effect of development on the course of the energy transition. With this we also evaluate whether democratization contributes to a more sustainable use of energy sources or not. A cross-country analysis is provided using information collected from the Polity IV dataset (Marshall and Jaggers, 2008) concerning the democracy level, combined with the dataset of Burke (2010) on energy shares and related variables. Second, the paper aims to provide a methodological contribution on regression model specification and estimation for energy shares, by addressing some challenging issues presented by this multinomial dependent variable that have been overlooked in earlier literature. Energy shares are defined on the interval $[0,1]$, and add up to one, being a multivariate fractional response variable. The relevance of taking into account the specific nature of this type of dependent variable in econometric modelling is demonstrated in Ramalho and Murteira (2016), who recommend the use of multivariate logit fractional regression models (MLFRM); see also Papke and Wooldridge (1996) and Ramalho et al. (2011) for former approaches on fractional regression models in which only two shares are present. The inadequacy of simple linear models to describe these variables is especially likely to occur in the framework under analysis, due to the fact that four out of the eight energy shares under analysis - the last four listed before - present values close to zero, which may lead to prediction of negative values for these shares. Moreover, the analysis of the marginal effects of the energy shares' determinants must take into account that they must add up to zero as, naturally, a change in a determinant, *ceteris paribus*, producing a positive effect in one or more shares, must necessarily produce a negative effect on others, as the shares add up to one. On the other hand, the incorporation of endogeneity in nonlinear models imposes additional challenges, but can be implemented using a control function approach; see Woodridge (2015). Basically, a control function, which consists of the residual of a regression of the endogenous variable on the exogenous variables and one or more instrumental variable(s), is added to the explanatory variables in the structural MLFRM. This gives rise to scaled versions of the parameters of the models, but provides the correct sign and significance of the effect of the explanatory variables, as well as their marginal effects on the shares, and a simple test to assess the presence of endogeneity.

Our main results highlight that both energy and democratic transitions are clearly interdependent, with nonlinearities implying that the energy ladder is escalated differently according to different levels of democratic institutions in place. For example, income growth drives democratic countries out of the hydroelectric and oil sources mostly to coal and nuclear and less to natural gas and renewable sources such as biomass, wind, and others. But for less democratic countries, the same increase in income does not impel countries out of the oil source to the coal source. On the contrary, they increase their oil and natural gas dependence while departing from hydroelectric and coal sources. Less democratic countries are virtually not on the way to renewable sources such as wind, solar, and others. As a consequence, less democratization also deters the path to a more sustainable use of resources.

This paper is organized as follows. Section 2 provides a brief survey of the literature addressing the potential causality between democracy, development, and energy transitions. Section 3 describes the dataset analyzed in this paper, providing some initial evidence on the relationship under analysis, and presents the major aspects of the MLFRM and their extension to deal with endogeneity. The empirical findings are discussed in Section 4. Finally, Section 5 presents some final remarks and policy implications.

2. Development, democratic and energy transitions

Energy transition through development has been recently analyzed by some authors. Most contributions are country-specific and use household data. Kroon et al. (2013) provide a meta-analysis of existing choice models investigating energy switching and stacking behavior in urban and rural areas in developing countries. The authors are unable to clearly identify the determinants of household energy mix. For example, Horst and Hovorka (2008) concluded that in an urban community in Botswana the energy ladder transition does not seem to happen. On the contrary, Lee (2013) found evidence for the energy ladder hypothesis in Uganda. Joon et al. (2009) concluded that besides income, other socio-cultural factors are also important to explain energy transition in a study applied to the households of the village of Jhajjar (Haryana), India. Energy transition in Brazil has been analyzed by Kiliber and Parente (2015) through a time-series between 1970 and 2010. Relative investment in renewable sources in the USA has been analyzed by Ohler (2015), concluding for a nonlinear relationship with income and that past unemployment may have a role as a predictor of investment in renewable sources of energy production.

Burke (2010) was the first to consider the determinants of the energy mix in a broad cross-section of countries. The paper uses as dependent variable the percentage of each of the eight energy shares under analysis and concludes that rising GDP *per capita* is associated with a transition from hydroelectric and oil sources of energy production to coal, natural gas, and nuclear sources and then to renewable sources such as wind, biomass, and thermal. This effect of development is robust to the endowments of natural resources related to each source of energy. Two subsequent articles considered additional variables as determinants of the energy mix. Arseneau (2011) presents evidence according to which Brazil, Russia, India, and China present different determinants of the energy mix (measured as proportions of energy usage) even after taking into account the endowments as in Burke (2010). More recently, Best (2017) analyzes if a country's stock of financial capital affects its ability to achieve energy transitions (measured as 10-year variations of shares) and concluded for a positive answer. We add a new factor to the analysis of the determinants of the proportion of the energy shares considered by Burke (2010): the democratization.

Few contributions have addressed the influence of politics or democratization features on the energy economics variables. Very recently, Cherp et al. (2017) compare the historical evolution of the energy transitions in Germany and Japan after the 1970s. While until the end of the 1980s, Germany and Japan had been remarkably similar concerning the energy transition, after the 1990s Germany became a leader in renewable sources of energy production while Japan relied on more nuclear energy. The authors argue that factors such as political power of owners of resources (such as coal in Germany or nuclear power in Japan) as well as abundance of resources (such as coal and wind in Germany) and fast rising demand (in Japan) may be at the roots of these different transitions. Previously, Moss (2014) showed how political shifts and socioeconomic conditions may have shaped the energy provision and consumption in the city of Berlin since the 1920s. In an earlier contribution, Hogan (2007) recognized the importance of democracy in energy related issues. Geopolitics, infrastructure, and security affects the supply of oil and gas around the world, despite the fact that natural gas is more evenly distributed around the world than oil reserves. It is argued that rents in oil and gas may prevent governments from promoting transition to other sources and thus also limit democratic transitions; less democratic countries may protect elites linked to the abundant natural resources (such as oil) and electricity sources conglomerates. In democracies, public acceptance of energy production have to be taken into account. For example, Kim et al. (2014) conclude that knowledge and trust in inspecting authorities are crucial determinants of nuclear energy production.

With specific attention to renewable energy sources, two recent

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