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Strategies to make renewable energy sources compatible with economic growth

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ABSTRACT

This paper focuses on the relationship between economic activity, and renewable and non-renewable energy consumption for the set of countries with the largest usage of each energy source. The dominance of one type of energy source could raise an unintentional barrier to a strategy of energy mix diversification. A panel of 28 countries was studied, using annual data for the time span 1995–2013. The ARDL approach was used to capture the short- and long-run effects. The Driscoll-Kraay estimator was used to attain robust results given the presence of the phenomena of heteroscedasticity, contemporaneous correlation, first order autocorrelation and cross-sectional dependence. Results suggest that renewable energy has not contributed to economic growth, while non-renewable energy has contributed. This finding should be incorporated in the definition of energy strategies, specifically by making renewable energy compatible with economic growth.

1. Introduction

Fossil fuels remain the main sources in the global energy mix and are associated with the increase of carbon dioxide (CO_2) emissions. The deployment of renewable energy sources (RES) can play a crucial role to reduce both (CO_2) emissions and fossil fuel dependency [1]. Thus, there is a worldwide trend to promote the use of renewable energy sources. Even so, these sources face severe entry barriers, mostly associated with market failures.

The entry barriers are widely analysed in the literature of industrial economics [2,3]. In fact, there are several kinds of entry barriers, namely: (i) initial investment; (ii) inelastic demand; (iii) restrictive practices; and (iv) research and development. The barriers to the diversification of energy sources, particularly RES, are also common and are analysed, for example, by Luttenberger [4]. According to general studies regarding entry barriers, both intentional and "innocent" entry barriers to RES can also be observed. This paper uses one of these entry barriers, which is the great dependence on, or even a dominant use of, a single source, to define the countries under analysis. This barrier could come from a substantial domestic availability of the resources (innocent barrier), or it could come from an intentional strategy to intensively use a specific source, namely fossil fuel, often due to lobbying by stakeholders in that source.

As such, a country's presence in the top ten of world electricity production by source, was the criterion used to select the countries under analysis, using the year 2012 as a reference. This criterion was based on the data available as of July 2015. When a country is on the list of more than one energy source, then it is considered only once. Annual data for the period 1995 to 2013 was used. Following the literature, energy variables (non-renewable and renewable energy consumption), economic variables (gross fixed capital formation, export of goods and services, and employment) and an environmental variable (carbon dioxide emissions) were used to explain economic growth. The ARDL approach in panel data proved to be suitable to detect the dynamics of the adjustments between the short- and long-run.

This paper contributes to the literature by revealing the relationships between energy sources and economic growth for this set of countries. Moreover, the paper provides support to the process of defining energy strategies, particularly those aiming to combine RES and economic growth. In the short-run, non-renewable energy has a positive impact on economic activity, while in the long-run, RES has a negative impact on economic activity. Energy strategies should enhance the economic rationality for the use of renewables, specifically by adopting demand-side measures to address their characteristics of intermittency.

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2. Literature review

The analysis of the causal relationship between energy consumption and economic activity has received much attention in the literature. Within this energy-growth nexus, four traditional hypotheses have been exhaustively tested [5,6], namely: (i) the *growth hypothesis*, which predicts a unidirectional causality, running from energy consumption to economic growth; (ii) the *feedback hypothesis*, which predicts a bidirectional causality between economic growth and energy consumption; (iii) the *neutrality hypothesis*, when there is no causality relationship between economic growth and energy consumption; and (iv) the *conservation hypothesis*, which consists of a relationship running from economic growth to energy consumption.

Although literature focusing on the nexus is abundant, there is no consensus on the outcomes. Indeed, dissimilar samples and econometric techniques can explain this lack of consensus [6]. The study of the nexus has evolved, from an aggregate perspective using primary energy consumption towards electricity consumption only. Moreover, the energy-growth nexus has also evolved from considering the energy sources as a whole, towards the analysis of each source individually, giving rise to several different nexuses. A summary of the results of the energy-growth nexus can be seen in Ozturk [6] and Menegaki [7]. This paper accompanies this trend, and focuses on energy consumption, by dividing energy into renewable and non-renewable according to its origin.

Diverse relationships between renewable energy consumption and economic growth can be found in the literature. A positive relationship [8], the lack of any link [9], as well as, a bidirectional relationship between renewable energy consumption, non-renewable energy consumption and economic growth [10], are examples of these relationships. We will return to the nature of these relationships, in the discussion section.

3. Data and variables

As stated before, the countries under analysis were chosen according to a single criterion: that the share of the country's electricity production by a specific source is present in the top ten of the countries for that source. According to the data available, the 28 countries selected, for the period 1995–2016, are the following: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, South Korea, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, the United Kingdom, and the United States of America. The countries Estonia, Iceland, Israel, Luxembourg, Slovenia and Turkey were excluded due to the lack of data for the entire period under analysis. The data analysis was performed using the software STATA 13.1.

The source of the variables was the World Bank, for: gross domestic product (constant 2005 US$); exports of goods and services (constant 2005 US$); population (number of people); unemployment (% of total labour force); labour force (total); and gross fixed capital formation (constant 2005 US$). The BP Statistical Review of World Energy was the data source for (CO_2) emissions and for each energy source, namely: oil consumption (in tonnes); gas consumption; coal consumption; nuclear energy consumption; hydroelectricity consumption; solar energy consumption; wind energy consumption; geothermal, biomass; and other renewables sources. All variables obtained by BP Statistical Review of World Energy, June 2015 are in million tonnes oil equivalent, except oil consumption and (CO_2) emissions. The variables gross fixed capital formation, exports of goods and services, CO_2 and employment, are used as control variables [11–13].

The variables used in the estimated models are as follows: (i) *YPC* (Gross Domestic Product per capita) – The ratio between Gross Domestic Product and total population; (ii) *NRESPC* (non-renewable energy consumption per capita) – This variable is calculated in two steps. The first step consists of the sum of oil consumption, gas consumption, coal consumption and nuclear energy consumption. The second step consists in dividing the above sum by the total population; (iii) *RESPC* (renewable energy consumption per capita) – This variable is also calculated in two steps. The first step consists of the sum of hydroelectricity consumption, solar energy consumption, wind energy consumption and geothermal, biomass and other renewable sources consumption. The second step consists in dividing the above sum by the total population; (iv) *XPC* (exports of goods and services per capita) – The ratio of exports of goods and services, and total population; *(v) GFCFPC* (gross fixed capital formation per capita) – Obtained by dividing the gross fixed capital formation by the total population. *(vi) CO2PC* (carbon dioxide emissions per capita) - Carbon dioxide emissions divided by the total population; and (vii) *EMP* (employment) – This variable is obtained in three steps. The first step consists of dividing unemployment by 100. In the second step, the first result is multiplied by the labour force, in order to obtain an absolute value for unemployment. In the third step, unemployment was subtracted from labour, in order to obtain the employment value.

4. Method

To study the relationship between economic growth, renewable and non-renewable energy consumption in countries with a dominant energy source, it is useful to analyse the dynamic effects in the short- and long-run. The Autoregressive Distributed Lag (ARDL) [14] model allows these effects to be analysed separately. It also allows for a different integration order of variables, i.e. I(0) and I(1) but not I(2), and different lag-lengths for the variables within the model. The dependent variable is *DLYPC*. The general specification of the ARDL model is the following:

$$LYPC = f\,(LNRESPC;\ LRESPC;\ LGFCFPC;\ LCO2PC;\ LXPC;\ DLEMP) \tag{1}$$

In equation (2), the short- and long-run dynamics can be observed, where the prefixes “L” and “D” denote natural logarithm and first difference of the variables, respectively. The subscripts t, I and j denotes the time period, country and lag length, respectively. α denotes the intercept, β_{ij} and λ_i the estimated parameters, and ε_{it} the error term.

$$\begin{aligned} DLYPC_{it} &= \alpha_i + \sum_{j=1}^{k}\beta_{1ij}DLYPC_{it-j} + \sum_{j=0}^{k}\beta_{2ij}DLNRESPC_{it-j} + \sum_{j=0}^{k}\beta_{3ij}DLRESPC_{it-j} \\ &+ \sum_{j=0}^{k}\beta_{4ij}DLGFCFPC_{it-j} + \sum_{j=0}^{k}\beta_{5ij}DLCO2PC_{it-j} + \sum_{j=0}^{k}\beta_{6ij}DLXPC + \sum_{j=0}^{k}\beta_{7ij}DLEMP_{it-j} \\ &+ \lambda_{1i}LYPC_{it-1} + \lambda_{2i}LNRESPC_{it-1} + \lambda_{3i}DLRESPC_{it-1} + \lambda_{4i}DLGFCFPC_{it-1} + \lambda_{5i}DLCO2PC_{it-1} + \lambda_{6i}DLXPC_{it-1} + \lambda_{7i}DLEMP_{it-1} + \varepsilon_{it}. \end{aligned} \tag{2}$$