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Are shocks to renewable energy consumption permanent or transitory? An empirical investigation for Brazil, China, and India

Giray Gozgor

Istanbul Medeniyet University, Faculty of Political Sciences, Unalan Street 5, Uskudar 34700, Istanbul, Turkey

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ABSTRACT

This paper investigates whether there is a unit root in renewable energy consumption in three large developing economies: Brazil, China, and India over the period 1971–2014. To do so, it uses four unit root tests assuming one structural break, two structural breaks, and more than two structural breaks. It observes that renewable energy consumption is a unit root process in Brazil, but it is found as stationary in China and India. The paper also tackles issues and challenges in the unit root test methodology in energy economics literature and provides implications for renewable energy consumption in three economies.

Contents

1. Introduction

This paper investigates stochastic properties of renewable energy consumption (stationary or unit root) in three large developing economies: Brazil, China, and India. Various papers have so far examined the relationship between renewable energy consumption and economic growth in many countries or in country groups by using different econometric tools (e.g., [1–4]). However, according to [5], examining the unit root characteristics (stochastic properties) of energy indicators can be seen as a "new branch of research in energy economics".

Indeed, understanding the unit root characteristics of renewable energy consumption is important for policy-makers and academic researches. The inferences are fourfold. First, if one finds that renewable energy consumption is stationary, this means that policy implications will merely have temporary impacts on renewable energy consumption. However, if one finds that renewable energy consumption has a unit root, policy implications will persistently affect the energy use [6]. This issue is also related to the "path dependency" or the "hysteresis hypothesis", i.e., whether shocks to energy markets have permanent impacts on renewable

E-mail address: giray.gozgor@medeniyet.edu.tr

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energy consumption [7]. In other words, if renewable energy consumption contains a unit root, this means that "permanent policy changes", (e.g., renewable portfolio standard), will be a more appropriate tool than "temporary policy stances", (e.g., tax or investment incentives) [7,8].

Second, this issue is related to shocks spillover from energy variables to other macroeconomic indicators (e.g., economic growth). If renewable energy consumption has a unit root, this implies that there can be significant effects on the economic growth, consumption, employment, inflation rate, labor productivity, real exchange rates, and trade openness [9–13].

Third, the results on transmission mechanisms of energy shocks affect the evidence on existing economic theories. For instance, the empirical investigations on output path (e.g., the real business cycle or the Keynesian theories), consumption level (e.g., the relative income or the permanent income hypotheses), unemployment dynamics (the natural rate of unemployment or the hysteresis hypotheses) can be associated with the stochastic properties of energy consumption variables [7,14].

Fourth, the issue is related to the forecast power or predictability of energy variables, due to the fact that if an energy variable is a unit root process that means it is impossible to forecast its future path [15]. This issue also relates to econometric modelling techniques, i.e., if the energy consumption is a unit root process, the suitable approach will be cointegration modelling and the error correction models. Contrarily, researchers should use the bounds testing approach and autoregressive-distributed lag (ARDL) estimations in the case of stationary renewable energy consumption.

This paper examines the unit root or stationary characteristics (stochastic properties) of renewable energy consumption in three large economies: Brazil, China, and India over the period 1971–2014. These economies have important characteristics not only for a rapid economic growth and an increasing share in the global economy, but also for significant renewable energy consumption; however, there are a few numbers of studies that have directly focused on these countries (e.g., [16]). Indeed, according to the recent data of the International Monetary Fund (IMF), these countries are the seventh, the first, and the third largest economies in the world, respectively [17].[1] In addition, these economies are also the largest countries in terms of renewable energy consumption: the average annual renewable energy consumption levels are reported in Table 1 for the largest ten renewable energy consumers for the period from 1971 to 2014. It can be observed that Brazil, China, and India are the sixth, the third, and the eighth largest renewable energy consumers in the world over the period under concern. When the data are analyzed for 2014, it can be seen that Brazil, China, and India, are the fifth, the second, and the seventh largest renewable energy consumers in the world. This implies that these countries are on a significant upward trend in renewable energy consumption.

In this paper, it is aimed to seek whether these trends in renewable energy consumption are policy-oriented or not. As we have mentioned, if renewable energy consumption is stationary, this means that policy implications will merely have temporary impacts on renewable energy consumption. On the other hand, if renewable energy consumption series have a unit root, policy implications will persistently affect renewable energy demand. To do so, four unit root tests are used [18–21] that takes endogenous structural break(s) into account in renewable energy consumption. The main contribution of this paper is that to implement these four unit root tests in the largest three developing economies in the world. The most important point in the unit root methodology is that some of these unit root tests assume one structural break [20], two structural breaks [19,21] and more than two structural breaks [18].

[1] The magnitude of economies are measured by the Purchasing Power Parity (PPP) Gross Domestic Product (GDP) in Millions of International $.

Table 1
Renewable energy consumption for top 10 consumers in the world (million tones oil equivalent): 1971–2014.

Countries	Period average	In 2014	Share of total in 2014
United States	15.490	65.02	20.5%
Germany	5.519	31.70	10.0%
China	4.387	53.08	16.7%
Japan	3.689	11.64	3.7%
Spain	2.977	16.26	5.1%
Brazil	2.777	15.44	4.9%
Italy	2.508	14.83	4.7%
India	1.893	13.91	4.4%
United Kingdom	1.672	13.23	4.2%
Canada	1.521	4.862	1.5%

Nevertheless, given that the number of observations is relatively small (44 observations) in the paper as well as in researches for the energy economics in general, one can trust on the results of the unit root tests that assume one or two structural breaks [14]. In other words, considering more than two structural breaks can lead to spurious empirical findings in the unit root methodology, and this issue is observed in the empirical results of the paper.

However, given that this paper focuses on the period from 1971 to 2014, the previous papers suggest that there are at least two events to create structural breaks in (renewable) energy consumption series (Energy Crises in the late 1970s and the Global Financial Crisis of 2008–09). Therefore, unit root test that assumes one structural break may also not capture all structural break created events in energy consumption series over the period 1971–2014.

In addition, given that the number of observations is relatively small in the energy economics literature, applying the Langrage Multiplier (LM) unit root test of [19] with two structural breaks can be problematic. Indeed [19], indicate that considering two structural breaks can yield to "substantial deviations in size and power" in the case of small sample [7]. Furthermore, it is found that the results of the unit root test of [21] can be more powerful for renewable energy consumption from 1971 to 2014 [22], and its results should be considered as "benchmark results" of the paper.

Finally, another challenging issue in the unit root test methodology in the energy economics literature is that to consider structural breaks both in constant and time trend terms [14]. When all of these issues and challenges in the energy economics literature are considered, it is observed that renewable energy consumption is a unit root process in Brazil; however, renewable energy consumption is found as stationary in China and India.

The remainder of the paper is organized as follows. Section 2 briefly reviews the literature on the energy consumption. Section 3 explains the data as well as discusses the features of the unit root methodology. Section 4 reports the empirical results and provides the discussion of results and the implications. Section 5 concludes.

2. Literature review

[23] firstly analyzed the unit root characteristics of energy consumption, and they considered the Augmented Dickey–Fuller (ADF) unit root test in 182 countries for the period from 1979 to 2000 within an annual data set. They observed that energy consumption had a unit root in 125 of 182 countries. Similar results were obtained by the paper of [24], which is considered 178 countries over the period from 1980 to 2006. These studies can be