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Are fluctuations in Japan's consumption of non-fossil energy permanent or transitory?

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HIGHLIGHTS

- The stationary property of non-fossil energy consumption is tested for Japan.
- The univariate and panel LM tests with multiple structural breaks are employed.
- The Fourier-type LM test under a non-linear framework is also employed.
- The series of nuclear energy consumption contains a unit root.
- Renewable energy consumption series are found to be stationary with breaks.

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ABSTRACT

This is the first empirical study to use annual data to probe the stationary property of non-fossil energy consumption in Japan. To understand the behavior of non-fossil energy from different sources, we adopt the univariate and panel Lagrange Multiplier unit root test, which can accommodate multiple structural breaks in data-generating processes, together with the Fourier-type Lagrange Multiplier test under a non-linear framework. Our empirical findings emphasize a difference between the stationary behavior of nuclear energy and renewable energy. Nuclear energy contains a unit root, which implies that random shocks to nuclear energy consumption, defined as regulatory change, may result in a permanent deviation from original target levels. However, renewable energy consumption series are found to be stationary, which implies that extant energy polices for such consumption could have a transitory effect. Thus, an innovation policy using effective and flexible incentive mechanisms needs to be adopted to enlarge renewable energy deployment.

1. Introduction

Non-fossil energy is an alternative energy source that does not require further reduction of limited resources, unlike fossil fuels such as oil, coal and gas. Non-fossil energy generally includes nuclear and renewable energy, the latter referring to energy forms that can be regenerated naturally and constantly within a biological time horizon and sustainably supplied [1–3]. Common renewable energy sources include hydropower, solar, wind, geothermal, biomass, and ocean energy [4]. Given the sustainable nature of non-fossil energy, it is not surprising that interest in its deployment has increased in recent years.

In 2010, Japan's electricity supply included the following sources: nuclear energy (27%), hydropower (7%), and non-hydro renewable energy (3%) [5]. There remain opportunities to expand the use of non-fossil energy in Japan. As a leading industrialized country, Japan has the world's third largest economy, following the United States and China. Furthermore, it ranks as the world's third largest oil and electricity consumer and fourth largest natural gas consumer. Because of the scarcity of domestic fossil fuel reserves, Japan relies heavily on fuel imports and, thus, is the world's second largest importer of coal, third largest of oil, and largest of liquefied natural gas [5].

Strong demand in recent decades for energy and energy-import dependence has triggered growing concerns over energy security and additional fears about the environmental consequences of carbon emissions [6]. In response, the Japanese government has designed an integrated energy policy planning structure [7], consisting of the Basic Act on Energy Policy and the Basic Energy Plan.

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Nomenclature

FLM	Fourier-type Lagrange Multiplier
$F_\mu(\hat{k})$, $F_\tau(\hat{k})$	F-statistic for the null hypothesis of linearity
LM	Lagrange multiplier
H_0	null hypothesis
k	frequency
$\hat{k}$	best frequency
SSR	sum of squared residuals
T	number of observation
T_B	break date
y_t	non-fossil energy consumption series in period t
ε_t	error term
$\tau_\mu(\hat{k})$, $\tau_\tau(\hat{k})$	value of the LM test for the null hypothesis of stationarity

Subscripts

0	base year
B	structural break
t	year of t

The government was required to formulate the Basic Energy Plan, which provides specific policy measures to promote energy supply and demand, engage in triannual reviews, and conduct any necessary revisions. The latest Basic Energy Plan, adopted in June 2010, includes ambitious targets for 2030. In terms of non-fossil energy, the nuclear power share in the electricity sector will increase to approximately 50% and renewable energy to 19%. However, in the wake of the 2011 Great East Japan Earthquake and tsunami and the ensuing Fukushima nuclear accident, a new plan entitled Innovative Strategy for Energy and the Environment was released in September 2012. The plan strongly suggested altering Japan's future energy mix, recommending that natural gas, oil, and renewable energy account for a considerable proportion of the energy market and nuclear power's role be reduced. By 2030, renewable energy should account for about 30% of electricity generation; three times the 2010 rate [5,8].

Although there is a growing number of empirical studies that investigate different aspects of non-fossil energy, further research is required to improve the understanding of their energy behavior, particularly in Japan. It is one of the world's major energy importers, and greenhouse gas emitters, and in the year of 2010 its carbon emissions accounted for nearly 4% of global emissions [9], which demonstrates its considerable and direct effects on world energy expenditure and the global environment. Against this backdrop, our present study attempts to explore whether shocks to non-fossil energy consumption in Japan are temporary or permanent by examining the stationary properties of Japan's consumption of non-fossil energy. Specifically, if the results favor a trending stationary process in non-fossil energy consumption, energy regulatory change (i.e., shocks) could have transitory and short-run effects, and as a result non-fossil energy consumption should revert to its original equilibrium level over time. It is in this case theoretically plausible to use past observations to forecast future consumption. However, if non-fossil energy consumption is found to be a non-stationary process, any shocks to non-fossil energy consumption may be persistent, meaning that a shock will result in a permanent deviation from the original path for non-fossil energy consumption. This also implies that for predictions of non-fossil energy demand, one would need to incorporate other related variables into the explanation of the behavior of non-fossil energy consumption. Moreover, non-stationary properties could be expected to be transmitted to key macroeconomic variables via flow-on effects and have persistent impacts on macroeconomic variables [3,10].

Considering the revised development strategies and targets for nuclear and renewable energy in the aftermath of the 2011 Fukushima nuclear accident, our present study seeks to answer the following important question: Are the stationary properties of nuclear and renewable energy heterogeneous? Answering this question will help to evaluate the effectiveness of regulatory change on nuclear energy as well as the necessity to enhance policy to prompt renewable energy deployment. To this end, we consider non-fossil energy consumption using disaggregated data. Moreover, to avoid false acceptance of the null hypothesis of a unit root, our empirical study adopts the univariate and panel Lagrange Multiplier (LM) unit root test with up to two breaks to test for stationary properties. Also, the Fourier-type Lagrange Multiplier (FLM) test under a non-linear framework is applied in the present analysis. The joint use of these tests and disaggregated data are expected to increase the power of the unit root test and facilitate differentiating relative energy behavior across different non-fossil sources, thus providing more reliable findings.

The remaining sections of the paper are as follows. Section 2 summarizes the related literature. Sections 3,4 and 5 demonstrate the data, econometric method, and empirical results, respectively. Section 6 presents some explanations and discussions associated with the main findings. The final section provides some conclusive comments and illuminates emerging policy implications.

2. Literature review

In the last 5 years, in view of the importance of energy consumption and related policy implications, an increasing number of empirical studies have investigated the stationary properties of energy consumption. Beginning with the work of Narayan and Smyth [11], the extant literature can be broadly categorized into three groups (see Table 1). One group applies univariate unit root tests with endogenous structural breaks to examine whether energy consumption is stationary [3,10,12–20]. Within this group, most studies have employed the Lee and Strazicich [21] Lagrange multiplier (LM) unit root test with multiple structural breaks to remedy the deficiency of the low power of traditional tests to reject the unit root null hypothesis. Also, some studies have conducted the Narayan and Popp [22] unit root test with multiple structural breaks. The main discovery from these works is that energy variables are stationary around a broken trend, although some works have reached ambiguous results or discovered that energy variables are non-stationary, even after allowing for structural breaks [23]. A second group uses panel unit root tests to investigate whether energy consumption contains a unit root [11,24–29] in the case of a short span of data. The Im et al. [30] test, Westerlund [31] panel unit root test with multiple breaks, and the Carrion-i-Silvestre et al. [32] panel stationarity test have been widely employed in empirical studies [11,24–29,33,34]. Most of these studies imply that, in general, energy production and consumption are stationary. Finally, the third group attempts to test for a unit root in energy variables under a non-linear framework, which has a better power of test compared with traditional tests [35–38]. Empirical results from the majority of these studies are ambiguous [35–37], except that the work of Maslyuk and Smyth [38] has found evidence of the unit root in energy variables.