Relationship Between Japan's Renewable Energy Generating Capacity and Economic Growth Based on ARDL Model

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Abstract: Under the background of the global energy shortage and Japan's Fukushima nuclear spill, Japan is faced with an important choice whether to abandon nuclear power or develop renewable energy. This paper used autoregressive distributed lag model to do the empirical analysis of the relationship between renewable energy generating capacity and economic growth, using the data of renewable energy generating capacity and real GDP between 1991 and 2010. The empirical evidence suggests that renewable energy generating capacity in Japan has emerged the ability to boost and promote economic growth in Japan in both the long-term and short-term. If the Japanese government determines to develop the renewable energy industry vigorously, Japan's economy is likely to usher in the take-off once again in the future, in addition that it will benefit the environmental mitigation and protection issues such as energy security.

Keywords: Abandon nuclear power, Autoregressive distributed lag model, Economic growth, Energy issue, Renewable energy generating capacity.

1. INTRODUCTION

With global energy consumption increasing and storage of non-renewable energy like coal and petroleum decreasing, energy depletion became the key obstacle to global economic recovery. On the other hand, the wide use of fossil fuels resulted in massive release of greenhouse gases and global climate warming, which posed serious pollution to the environment and thus more and more countries began to pay attention to the development and utilization of renewable energy. Rather than energies like conventional fossil energy, large and medium-scaled hydro power energy or nuclear fission energy, renewable energy refers to energies like solar energy, wind energy, biomasses energy, micro-hydro energy, geothermal energy and marine energy. These energies are resourceful, renewable and clean, which are the most promising alternative energy sources. According to METI statistics of January 10, 2014, renewable energy equipment which Japan imported has begun power generation equipment amounted for 5.852 million kW from July 2012 when "Renewable Energy Special Measures Act" enacted to the end of October 2013, the equivalent of six nuclear power generation plants.

Under the background of global energy shortage and Japan's Fukushima nuclear spill, the development of renewable energy is regarded as another industrial revolution promoting Japan's economic growth. Although "nuclear abandonment" is undoubtedly logical, can Japanese economy really get rid of the dependence on nuclear power? Can renewable energy really complete energy supply gap caused by Japanese nuclear power plant's shutting down? With Japan's long and lasting economic downturn and its power industry faced with changes and transition, can implementing the renewable energy policy vigorously really make the Japanese economy take off once again?

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2. LITERATURE REVIEW

As an indispensable condition for economic growth, relationship between renewable energy and economic growth has been widely concerned. Scholars abroad studied the relationship between them mainly from three viewpoints currently.

Firstly, there is a two-way relationship between them. Masih A.M.M and Masih R. (1996) concluded a two-way causal relationship between energy consumption and economic growth in Pakistan [1]; Glasure and Lee (1997) concluded a two-way causal relationship between energy consumption and economic growth in both South Korea and Singapore using techniques of co-integration and error correction model [2]. Secondly, there is a one-way relationship between them. Kraft, A. and Kraft, J. (1978) using data from 1947 to 1974 of the United States, found that there was only a unidirectional causality from GNP to energy consumption [3]. Ugur and Ramazan (2003) used co-integration and vector error correction model technique, finding energy consumption promoted economic growth in Turkey, France, Germany and Japan, while the direction was just opposite in Italy and Korea [4]. Thirdly, there is no relationship between them. Akarca and Long's (1980) research found that when using the same time series data in shorter sample period than that used by Kraft (1978), similar conclusion can't be drawn [5].

Domestic research mostly started in the 21st century. Lin Boqiang (2001) used co-integration and error correction model to further study the determinants of China's energy

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demand and concluded there was a long-term equilibrium relationship among total energy consumption, GDP, energy prices and its structural changes [6]. Wang Ying (2008) concluded that there was a stable co-integration relationship between renewable energy consumption and economic growth and China's renewable energy consumption was a unidirectional significant Granger cause to GDP growth [7]. Guo Haihua (2010) proved that there was one-way causal relationship from energy consumption to economic growth in China [8]. Wang Liang (2013) concluded that there existed long-time stable co-integration relationship between renewable energy consumption and economic growth in China [9].

In previous studies, the conclusions were quite different due to different economic systems, different level of economic development and economic form at different periods in different countries. And literatures about the relationship between renewable energy generating capacity and economic growth are relatively rare. In addition, previous studies mainly adopt traditional co-integration and vector error correction (VECM) model, while VECM approach requires a large number of endogenous variables, exogenous variables, as well as precise lag order, trend item, intercept, which would affect the robustness of the model; Moreover, the "Co-integration-Error Correction–Causal" paradigm requires the variables to be single-order co-integration. Compared with traditional co-integration test, auto-regressive distributed lag model (ARDL) is a co-integration method with many advantages such as lower requirements of sample capacity, less requirement on the stationary of data. So the method is applicable whether the variables in the model are pure I(0) or I(1) or a mixture of both [10]. Therefore, this paper uses the ARDL method to discuss the relationship between renewable energy generation and economic growth in Japan and this paper will discuss the application prospect of renewable energy in Japan.

3. THE PRESENT SITUATION OF RENEWABLE ENERGY GENERATING CAPACITY IN JAPAN

Currently, the main features of the energy supply in Japan is as follows. First, electric energy is prominent. Japan has the highest ratio among the developed countries in converting all kinds of energy into electricity; Second, oil is being overly dependent on; Third, nuclear power takes a large proportion, and nuclear power generating capacity accounted for 40% of total electricity generating capacity; Fourth, the amount of natural gas energy used is relatively small; Fifth, thermal power is dominant and hydropower potential is limited [11].

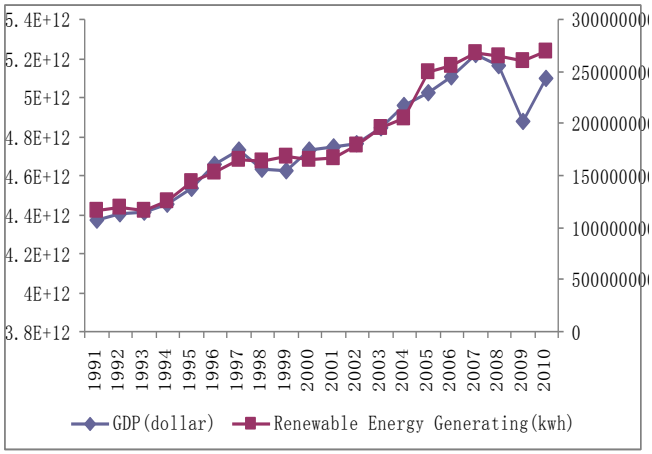
(1) Solar energy. Currently, Japan ranked the top country in the development and utilization of solar energy. The use of solar thermal energy in Japan began from the second oil crisis happened in 1979 and reached its peak in 1990. Solar power technology innovation is increasing, the energy conversion rate is improving continuously and its cost is also the lowest in new energies. Solar power is divided into solar photovoltaic and solar thermal power generation. In 2009 Solar energy generating capacity was 2758 Gkw, ranking third in the world.

(2) Wind energy. Owing to the unique geographical landscape of an island country and the long coastline, Japan is very rich in wind resources. But due to the geographical location of Japan—an island country, the wind airflow is turbulent, causing the output frequency unstable, so that the utilization of power equipment is low, only about 20% to 30%, and the cost is also very high. Meanwhile, energy generated from wind is difficult to store, which is the key technique problem for wind power currently. Therefore despite Japan's richness in domestic wind resources, wind power generating capacity in Japan was only 2949 Gkw in 2009, only ranking 13th in the world.

(3) Hydroelectric energy. Hydropower generating capacity in Japan was 91 TWh in 2010, accounting for 2.6% of the total global hydropower generating capacity, ranking eighth in the world.

The Japanese government made the "new energy plan" in 1994, planning the solar energy generating capacity to be 4600 MW in 2010. In early 2003 Japan issued an official report, saying it would launch the bio-energy program officially from 2010, and would develop renewable energy together with the United States and the European Union, expecting to invest $ 260 billion to build 500 demonstration areas, while related products and technology would be an important part of Japan's new industrial strategy.

In the rapid development period of the world's renewable energy industry, the total amount of renewable energy used in Japan is also increasing. Renewable energy generating capacity increased from 11.65 billion kwh in 1991 to 26.909 billion kwh in 2010, an increase of approximately 1.31 times.



Data from the World Bank http://data.worldbank.org/country/japan

Fig. (1). Japanese renewable energy generating capacity and GDP trend.

While renewable energy generating capacity was increasing, Japan's GDP increased from $437 billion in 1991 to $509.4 billion in 2010, an increase of approximately 16.6%. As can be seen from Fig. (**1**), the changing trend of the amount of renewable energy generating capacity and the changing trend of the GDP in Japan has been roughly the same. It can be inferred preliminarily that there is some

positive correlation between the amount of renewable energy generating capacity and economic growth in Japan.

4. EMPIRICAL ANALYSIS ON THE RELATIONSHIP BETWEEN JAPANESE RENEWABLE ENERGY GENERATING CAPACITY AND ECONOMIC GROWTH

4.1. Data Sources

Data in this paper mainly involve renewable energy generating capacity and economic growth in Japan. Economic growth is measured by Japanese gross domestic product (GDP). To eliminate inflation factor, the GDP takes 2000 as the base year, and is converted into constant price dollar GDP; Data of renewable energy generating capacity use the electricity production data of renewable energy, including electricity generated by hydropower, geothermal power, solar energy, tidal energy, wind energy, biomass and bio-fuels, represented by REC. The sample interval is from 1991 to 2010 and the original data are from the World Bank official website. Natural logarithm transformation doesn't change the co-integration relationship of the original variable while linearize its tendency and eliminate the hetero-skedasticity phenomena of the time series at the same time so this paper would perform natural logarithm transformation on the researched variables in the analysis followed.

4.2. Stationary Test

Although ARDL method doesn't require the uniformity integration properties of the variables, yet the testing statistic F constructed by Pesaran *et al*. on bound testing is based on I(0) or I(1) data. Therefore, unit root test of variables is needed before applying ARDL method. Eviews6 software is used to do unit root test and ADF, PP, KPSS testing method are adopted respectively. From the test results (Table **1**), logarithm series of GDP (LGDP) rejects the null hypothesis at the significance level lower than 5% (ADF test), namely LGDP~I(0). First order difference of the logarithm series of renewable energy generating capacity (DLREC) rejects the null hypothesis at the significance level lower than 5% (ADF test), namely LREC~I(1), which is in full compliance with what ARDL model required for stationary test. So ARDL bounding test can be conducted on the two series.

4.3. ARDL Bounding Test

Use ARDL bounding test method to test whether there is a co-integration relationship between LREC variables and LGDP variables. Use Software Microfit4.1 to conduct hypothesis testing on the long-term coefficient λ_i (i=1,2 in this paper). The lag order of first-order differential series is based on SBC criterion and the lag order is determined to be 4. As the paper involves the association relation of two variables, there are two models to conduct bounding test. Results output by Microfit4.1 are summarized in Table **2**. When economic growth (LGDP) is taken as the dependent variable, F test value is 7.8825 and the null hypothesis is rejected at the significance level of 1%. There is a long-term co-integration relationship from renewable energy generating capacity to economic growth. When renewable energy generating capacity (LREC) is taken as the dependent variable F is 0.12114 and the null hypothesis is accepted. There is no long-term co-integration relationship from economic growth to renewable energy generation capacity.

4.4. Parameter Estimation

According to the results of ARDL bounding test between LREC and LGDP, there is a long-term co-integration relationship from LREC to LGDP. According to ARDL model ARDL (p, q, n) between LREC and LGDP can be written as:

$$\ln rec = \alpha_0 + \sum_{i=1}^{n} \alpha_1 \ln rec_{t-i} + \sum_{i=1}^{p} \alpha_2 \ln gdp_{t-i} + \mu_t \quad (1)$$

Use Microfit4.1 software to estimate the long-term co-integration coefficient among the variables and the corresponding error correction model ECM. First restrict the maximum lag value to be 4 based on SBC Criterion and sample size. $(4+1)^{1+1}$ regression equations are estimated by Microfit4.1 software. Then use SBC criteria and AIC criteria to determine the ARDL between Japanese renewable energy generation capacity and economic growth, and the result shows ARDL (3, 0, 4) is selected to estimate in this paper. According to the estimation results of ARDL (3, 0, 4) (Table **3**) by Microfit4.1 software, F value of ARDL (3,0,4) is 95.7484, and coefficient of determination is 0.95226. Model Estimation is highly significant as a whole, the

Table 1. Unit root test on LGDP, LREC.

Variables	ADF Test		PP Test		KPSS Test	
	Trend Item Included	Without Trend Item	Trend Item Included	Without Trend Item	Trend Item Included	Without Trend Item
LGDP	-3.750940** (0.0450)	-1.132406 (0.6803)	-2.482315 (0.3316)	-1.015171 (0.7257)	0.086729	0.573545**
DLGDP	-4.721498*** (0.0083)	-4.875613*** (0.0014)	-4.562674** (0.0101)	-4.647564*** (0.002)	0.454579***	0.301345
LREC	-3.651530* (0.0574)	-0.615771 (0.8450)	-2.076156 (0.5254)	-0.632968 (0.8408)	0.057059	0.589125**
DLREC	-3.476514* (0.0817)	-3.207310** (0.0414)	-3.353845* (0.0895)	-3.438499** (0.0232)	0.072853	0.075705

Note: (1) Optimal lag order of ADF test is determined by the improved Akaike information criterion (AIC) and Schwarz Bayesian Information Criterion (SBC) ; (2) In ADF and PP tests, H0= there is unit root in the series; In KPSS test, H0= the series is Stationary; (3) ***, ** and *denote significance level at 1%, 5% and 10% respectively; (4) values within ( ) are p values.

Table 2. Bounding co-integration test of the logarithmic series of LGDP and LREC.

Dependent Variable		Model		F Test Value	
LGDP		FLGDP (LGDP/LREC)		7.8825***	
LREC		FLEC (LREC/LGDP)		0.12114	
critical value 1% of bound co-integration testing		critical value 5% of bound co-integration testing		critical value 10% of bound co-integration testing	
I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
4.614	5.966	3.272	4.306	2.676	3.586

Note: ***indicates the critical value of significance level 1% in bounding test.

estimated value of LREC long-term coefficients is 0.18345, its T value is 17.8925, and the estimated result is highly significant. This suggests that when the renewable energy generating capacity increases by one unit, Japan's GDP would increase by 0.18345 units in the long term. From ARDL-EMC estimation results (Table **4**), the estimated value of the short-term coefficient is also highly significant statistically. The impact value of renewable energy generating capacity to economic growth in the short-term is 0.19138 which means when the renewable energy generating capacity increases by one unit, Japan's economic growth would increase by 0.19138 unit. The estimation value of the coefficient of error correction term ECM(-1) is -1.0432 and T value is -6.0120, which is highly significant statistically and their signs are correct(negative), indicating that if economic growth deviates from the long-term equilibrium relationship with the renewable energy generation capacity in the short-term, the non-equilibrium state of renewable energy generation capacity and economic growth would be adjusted in current period with the speed -1.0432 to the previous period to pull it back to the long-term equilibrium.

Table 3. Long-Term Equilibrium Coefficient of ARDL (3, 0, 4).

Independent Variable	Coefficient	T Value [Probability]
LREC	0.18345	17.8925[0.000]
INPT	24.8618	102.0556[0.000]
R-Bar-Squared= 0.95226; DW-statistic = 2.3436; F-stat=95.7484[.000]		

Note: INPT denote the constant term; values within [] are p values.

4.5. Granger Causality Test

Test results in Table **5** indicate that when the significance level is lower than 5% and the lag length is 1 and 2, the renewable energy generation capacity is the Granger reason of Japan's economic growth.

Table 4. Short-Term Equilibrium Coefficient of ARDL (3, 0, 4).

Independent Variable	Coefficient	T Value [Probability]
dLGDP1	0.42138	2.6557[0.018]
dLGDP2	-0.45216	-2.3810 [0.031]
dLREC	0.19138	5.3154[0.000]
dINPT	25.9369	6.0939[0.000]
ecm(-1)	-1.0432	-6.0120[0.000]
R-Bar-Squared= 0.68175 ; DW-statistic = 2.3436; F-stat= 11.1752[.000]		

Note: INPT denote the constant term; values within [] are p values.
dLGDP = LGDP-LGDP (-1), dLGDP1 = LGDP (-1)-LGDP (-2), dLGDP2 = LGDP (-2)-LGDP (-3), and so on.

CONCLUSION

From the analysis of the relationship between Japan's renewable energy generation capacity and economic growth in 1991-2010, Japan's GDP would grow by 0.18345% as the long-term renewable energy generating capacity increased by 1%, and Japan's GDP would grow by 0.19138% as the short-term renewable energy generating capacity increased by 1%. And the renewable energy generation capacity is the Granger reason of economic growth in Japan which reflects that the renewable energy generating capacity in Japan has shown the ability of stimulating economic growth in Japan. But the motiving power is still weak as Japanese government has been emphasizing on nuclear power generation. After all renewable energy generation only accounts for about 8% of the total generating capacity, so the government subsidies can't compare with what nuclear power has.

However there is huge space for the development and utilization of renewable energy in Japan. First Japan is a country extremely scarce of natural resources with very limited primary energy reserves and has to import large quantities of resource like coal oil and natural gas, which

Table 5. Results of Granger causality test.

Lag Order	Granger Causality	F Value	P Value	Conclusion
1	LGDP is not the Granger reason of LREC	0.38154	0.5454	accept
	LREC is not the Granger reason of LGDP	6.62833	0.0204	reject
2	LGDP is not the Granger reason of LREC	0.14073	0.87	accept
	LREC is not the Granger reason of LGDP	9.98555	0.0024	reject

threatens sustainable economic development of Japan seriously. If Japan had begun to focus on solving this problem after the Fukushima nuclear leakage incidents and promoting renewable energy projects vigorously, Japanese economy would be likely to take off once again in the future besides benefiting on issues such as environmental protection and emission reduction. Secondly, Japan has many advantages in developing renewable energy. With a vast coastline and abundant wind resources, Japan has a unique advantage in exploiting and using offshore wind power to generate electricity on a large scale. As Japan is also a technically powerful nation mastering the core technology of renewable energy, commercial operation on renewable energy is not difficult for Japan. Finally, huge economic losses, negative impact on society and ecological destruction brought by the Fukushima nuclear accident strengthened the determination and confidence of social public in Japan in developing renewable energy. Fukushima nuclear leakage is a heavy blow to Japan. But it is also an opportunity for Japanese power industry to be transited to renewable energy from another perspective. "Nuclear abandonment" and the development of renewable energy have become a consistent demand for social public in Japan. If Japanese power industry transits to the renewable energy successfully "Japanese Experience" will be competing to draw by the rest of the world.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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