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Multivariate Cointegration and Causality between Exports, Electricity Consumption and Real Income per Capita: Recent Evidence from Japan

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ABSTRACT: The current literature on the relationship between electricity, exports and economic growth is mixed. This paper examines the relationship between exports, electricity consumption and real income per capita in Japan using time series data from 1960-2007. We applied bounds testing procedure developed by Pesaran *et al.,* (2001) and found that there is cointegrating relationship between electricity consumption, exports and economic growth. On establishing cointegration, the causal relationship electricity consumption, exports and economic investigation was investigated within a Vector Error Correction Model (VECM) framework. We found that in the long run, there is causality from exports and real GDP per capita to electricity consumption.

Keywords: Exports; Electricity consumption; Real Income per capita; Japan
JEL Classification: Q43, C32

1. Introduction

Energy security is now seen an important perquisite for sustainable economic development. Many countries are now implementing a number of measures to ensure energy security and reduce greenhouse gas emissions. Special Focus of the international community has been drawn to APEC region (Asia Pacific Economic Cooperation) where World's some of fastest growing economies are located. These economies are now implementing number of programs to improve efficiency in energy use. These include promotion of good energy practices and encouraging investment in energy efficient technologies. Although, today Japan is the world's third largest economy after USA and China, World Bank (2010), it has limited amount of energy resources. Japan, infact imports about 97% of energy resources from overseas,(Ministry of Economy, Trade and Industry, Japan, 2010). Given its limited energy resources , a report by APEC revealed that Japan in 2008 imported 99% of oil,98% of its coal and 96% of gas. It has about some 355million tonnes of coal reserves and 20.9 billion cubic metres of gas reserves, APEC (2010).Furthermore; Japan has some 277.671 GW (gigawatt) of installed generating capacity. Electricity is generated from thermofuel (70.5%), hydro (6.5%) and nuclear (20.1%), others (2.8%), Energy Data and Modelling Center (2009). Despite, the limited energy resources, energy consumption in Japan's commercial, residential and transport sector is rising due to a number of factors such as changing life style and higher rate of vehicle ownership. Compared to other countries such as Germany, France, US, India, UK, China, Canada and Russia, energy sufficiency ratio in Japan is low (Ministry of Economy, Trade and Industry, Japan, 2010). The Japanese government is now implementing a number of measures to achieve energy security and reduce carbon emission.

For example, in 2006 Basic Law on Energy Policy was enacted. Later on, in 2008, the government introduced New National Energy Strategy in light of global developments. This strategy was heavily focused on achieving energy security. Under this strategy, the government targeted to improve energy efficiency to 30%, increase share of electric power generated from nuclear energy to 30-40%, cut down the oil dependency ratio to about 80% and increase domestic investment in oil exploration and related development projects. In 2010, the government further modified the Energy

Plan by adding two important principles that is "energy based economic growth" and "reform of the energy industrial structure". These two new principles add to already existing principles of energy security, economic efficiency and environmental suitability. The Revised Strategic Energy Plan sets out a number of targets for 2030.These includes doubling the energy self sufficiency ratio and energy independence ratio to 36% and 70% respectively, reducing carbon emission by the residential sector by 50% and enhancing energy efficiency in the industrial sector. Japan electricity price has been amongst the highest of the developed countries (APEC, 2010) and this is possibly explains a series of reforms in the electricity sector. In earlier study by OCED (1998) found that Japan has highest electricity prices in OCED.

Table 1. Electricity Power Consumption (kWh per Capita) for Selected Asian Countries

	Japan	India	China	Malaysia	Singapore	Phillipines
1971-1975	3,848	105	171	370	1,497	283
1976-1980	4,601	134	243	573	2,315	336
1981-1985	4,985	172	318	786	3,068	341
1986-1990	5,919	242	446	1,031	4,361	339
1991-1995	6,953	328	663	1,621	5,551	359
1996-2000	7,735	389	890	2,533	6,974	468
2001-2005	7,964	438	1,401	3,037	8,041	554

Source: WDI (2010) Five Year Average

Table 1 compares the electricity power consumption (Kwh per Capita) of selected Asian countries. It can be noted from the table that, Japan's electricity power consumption (Kwh per Capita) is quite high compared to other large economies such India and China. An important implication of this is that Japanese government should devise policies to reduce electricity wastage and invest in alternative sources of electricity generation. The recent damage to nuclear power plants due to earthquake can put considerable pressure on the Japanese economy to maintain its growth performance. According to International Energy Agency (2011), the damage to the power sector has been greatest in the areas of Tokyo Electric Power Company (TEPCO) and that of Tohoku Electric Power Company (Tohoku-EPCO).The report further found that some 9.7GW of TEPCO, Tohoku-EPCO and Japan Atomic Power nuclear plant capacity was shut down due to the earthquake. Rolling blackouts of 3 hours in 5 areas have been announced by Tokyo Electric Power Company. In the refining sector, 6 refineries with a capacity of 1.4mb/d (millions of barrels per day) were shut down. These 6 refineries accounted for about 30% of Japan's total refinery capacity, IEA (2011). Policies to address any possible energy crisis must implement urgently to avoid any adverse effect on the export sector. The electricity industry in Japan is controlled by 10 vertically integrated regional companies, dominated by Tokyo Electric (TEPCO) and Kansai Power, Thomas (2006). The efforts of the government to liberalise the industry is yet have a major impact. Any future electricity shortage can cause serious disruption to production of goods in export sector and hamper economic performance.

Nuclear power plants have been important source of electricity in Japan. Though there are some safety issues associated with this form of power generation, nuclear power generation does not produce greenhouse gases and considered an important tool in address in energy supply stability, environmental protection and economic efficiency. Further, nuclear energy is recognized now as an important source of electricity.Infact, promotion of nuclear energy is one pillars of Japan's Energy Plan. The recent earthquake however, has raised questions over safety issues with such forms of energy indicating that policies that promote such forms of energy should equally focus on the socio – economic effects. The recent natural disaster in Japan that shocked the entire world is yet to show its full effects on the Japanese economy, neigbouring Asian economics and other developed economies. While some believe that the Japanese economy is strong and can rebound quickly, such convincing statements are best evaluated against empirical evidence. In a report by IMF (2011) has warned that neigbouring Asian economies are likely to be affected through trade channels. It known that damage has been done to nuclear power plants which is an essential source of electricity generation in Japan. In light of these developments, it is important to understand the relationship between electricity consumption and economic growth.

Bulk of earlier papers published in top energy journals has tried to establish the relationship between electricity consumption and economic growth within a bivariate regression, see Apergis and Payne (2010) for an excellent review. However, in the recent years, the two variable regressions has come under fire from researchers as it is argued that estimated relationship suffers from omitted variable bias and causality tests from bivariate models can be misleading, see Lean and Smyth (2010) for more discussion on this. Furthermore, in a study by Wolde-Rufael (2009) found that causality results for number of African changed when other variables such as capital and labor were included. Since earlier studies examined cointegration and causality within a bivariate framework, this probably explains why even today, the question of how important electricity is for economic growth remains open. We specifically examine the relationship between electricity consumption and economic growth, including exports as an additional variable. Exports seem to a very important variable and electricity consumption can influence the performance of the export sector.

The objective of this paper is twofold. First of all, we aim to establish if the three variables are cointegrated; implying that they move together in the long run. This would be interesting finding in light of recent development in cointegration literature. It is of interest to know if electricity consumption and real income per capita share a common trend in the long run. Secondly, we investigate the causal relationship between exports, electricity consumption and economic growth within a Vector Error Correction Model Framework. It is expected that by including exports as an additional variable in the analysis, one can get a better picture of causal relationship between electricity consumption and economic growth. If there is uni-directional causality from electricity consumption to economic growth, then growth hypothesis is supported, this would imply that electricity consumption has significant influence on economic growth directly. Thus policies that reduce electricity consumption can have adverse impact on economic growth. If there is uni-directional causality from economic growth to electricity consumption, then conservation hypothesis is supported and policies that reduce electricity consumption will not have adverse impact on economic growth. Evidence of bidirectional causality between electricity consumption and economic growth supports feedback hypothesis. In this case, policies that reduce electricity consumption shall adversely affect economic growth and these economic fluctuations shall be transmitted back to electricity consumption. Finally, if there is no causality between electricity consumption and economic growth, then this implies that electricity conservation policies will not affect economic growth. These findings can be use to policymakers in trade as well as energy. In this study, we employ bound testing procedure to test if there is cointegrating relationship between the variables. The advantage of bound testing procedure is that, it can be applied without knowing the stationary properties of the variables. Thus it, spares us from pre-testing for unit roots. Moreover, bounds testing procedure is well suited to small size.

The rest of the paper is organized as follows: Section 2 gives an overview of empirical literature. Section 3 explains the data sources and results of unit root tests. Section 4 examines the empricial methodology and empricial results. Section 5 discusses conclusions and makes some important policy recommendations.

2. Review of Empricial Literature

Binh (2011) examined the nexus between energy consumption and economic growth in Vietnam and found that there is cointegrating relationship between energy consumption and economic growth. He also finds evidence of uni-directional causality running from electricity consumption to economic growth. Adom (2011) finds evidence of uni-directional causality running from economic growth to electricity consumption, thus supporting the growth-led energy hypothesis in Ghana. Payne (2010) surveys the literature on causal relationship between electricity consumption and economic growth and concludes the evidence on causal relationship between electricity consumption and economic growth is mixed. His analysis show that 31.15% of studies supported the neutrality hypothesis, 27.87% of the studies supported conservation hypothesis; 22.95% supported the growth hypothesis; and 18.03% supported the feedback hypothesis. Smyth and Lean (2010a) examined the causal relationship between aggregate output, electricity consumption, exports, labor and capital in a multivariate model for Malaysia by employing modified version of the Granger causality test proposed by Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996) -TYDL. They found evidence in support of bi-directional causality between aggregate output and electricity consumption and exportled growth hypothesis in Malaysia. Smyth and Lean (2010b) used time series data from 1970-2008 to study the causal relationship between economic growth, electricity generation, exports and prices. They found evidence of uni-directional causality running from economic growth to electricity consumption.

Yoo and Kwak 2010) find evidence of long run relationship between electricity consumption and economic growth in Venezuela and Columbia. Lorde et al (2010), finds a long run relationship between electricity consumption and economic growth in Barbados.Chandran, Sharma and Madhavan (2010) examine the relationship between electricity consumption and growth in Malaysia, including price. They find evidence of long run relationship between the variables. Smyth and Lean (2010c) apply Johansen Fisher panel cointegration test and finds that there is a long run relationship between carbon dioxide emission, electricity consumption and output in ASEAN countries. Ciarreta and Zarraga (2010) applies panel data methodology to examine the long run relationship between economic growth and electricity consumption in 12 European countries. Their study included energy prices as an additional variable and found evidence that three series move together in the long run. Acaravi and Ozturk (2010) do not find evidence of cointegration between electricity consumption per capita and real GDP per capita in 15 transition countries. Ozturk and Acarvci (2011) investigate the short-run and long-run causality issues between electricity consumption and economic growth in the selected 11 Middle East and North Africa (MENA) countries by using Autoregressive Distributed Lag (ARDL) bounds testing approach of cointegration and vector error-correction models for 1971-2006 period. The cointegration test results show that there is no cointegration between the electricity consumption and the economic growth in three of the seven countries (Iran, Morocco and Syria). Thus, causal relationship cannot be estimated for these countries. However, the cointegration and causal relationship is found for four countries (Egypt, Israel, Oman and Saudi Arabia). The overall results indicate that there is no relationship between the electricity consumption and the economic growth in most of the MENA countries. Further evidence indicates that policies for energy conservation can have a little or no impact on economic growth in most of the MENA countries.

Narayan and Smyth (2009) find positive effects of electricity consumption and exports on output in a panel of six Middle Eastern Countries.Abosedra et al(2009) finds long run relationship between electricity consumption and real GDP. Odhiambo (2009) finds that electricity, employment and economic growth in South Africa. Akinlo (2009) find evidence of long run relationship between electricity consumption and economic growth. Ghosh (2007) finds that electricity supply, employment and real GDP in India are cointegrated. Narayan and Singh (2007) finds that electricity consumption, employment and real GDP are cointegrated in Fiji.Ho and Siu (2007) finds a long run relationship between electricity consumption and GDP for Hongkong.Mozumder and Marathe (2007) found that there is unidirectional causality from per capita GDP to per capita electricity consumption in Bangladesh. Tang (2008) studied the relationship between electricity consumption and economic growth in Malaysia and did not find any evidence of cointegration. Yoo (2006) also did not find any evidence of cointegration between electricity consumption and economic growth in ASEAN countries. Altinay and Karagol (2005) find evidence of uni-directional causality running from electricity consumption to GDP for Turkey.

Lee and Chang (2005) find similar evidence for Taiwan. Narayan and Smyth (2005) find that electricity consumption, employment and real income are cointegrated. However, other studies have found evidence of unidirectional running from economic growth to electricity consumption. These include Ghosh (2002) for India, Hatemi and Irandoust (2005) for Sweden. Other studies have found evidence of uni-directional causality running from electricity consumption. Shiu and Lam (2004) found that electricity consumption and economic growth in china are cointegrated. Yuan et al., (2007) finds that electricity consumption and economic growth are cointegrated. Wolde-Rufael (2006) finds mixed evidence on causal relationship between electricity consumption and real GDP per capita. Squalli (2007) finds evidence of long run relationship between electricity consumption and economic growth for all Organization of Petroleum Exporting Countries using bound tests. The author also found evidence of importance of electricity consumption for economic growth in Indonesia, Iran, Nigeria, Qatar and Venezuela. For a detailed literature survey on energy consumption-economic growth nexus, see the study by Ozturk (2010).

3. Data Sources and Unit Roots Tests

We sourced data for the study from World Development Indicators (2010).All variables were transformed into natural logarithm in order to avoid the problem of heteroscedasticity and obtain elasticities. The three variables we used in the study were real income per capita, electricity consumption (kwh per capita) and exports covered for the period 1960-2007.We start our analysis by examining the unit root properties of the data series. A series is said to be stationary if it has a constant mean, variance and auto covariance. While it is known that, bound testing procedure does not require pretesting for unit root, in order to conduct Granger Causality test the variables must be I(1).While regressing a nonstationary time series on another nonstationary time series may produce a spurious regression, if there is long run relationship between the variables , then such regression may not be spurious but meaningful. Regardless , we conduct the unit root test to ascertain the stationary properties for conducting Granger Causality test and ensure that variables are not I(2)The Augmented Dickey Fuller test corrects for higher order serial correlation through lagged difference terms. On the other hand, a Phillips-Perron test makes non-parametric correction for residual serial correlation Monte Carlo studies have indicated that Phillips-Perron test has greater power than standard ADF test (see for example, Banerjee et al, 1993; Choi,1992).

Unit Root tests

The ADF test involves estimating the following equations using least squares:

$$\Delta Y_t = \delta + \lambda T + \beta Y_t + \sum_{t=1}^{\rho} \varphi_i \Delta Y_{t-1} + u_t \quad (1)$$

$$\Delta Y_t = \delta + \beta Y_t + \sum_{t=1}^{\rho} \varphi_i \Delta Y_{t-1} + u_t \quad (2)$$

Where Y_t is the variable tested for unit root; ρ is the lag length; T is the time trend variable while, Δ is the difference operator and δ is the constant term. The lag length for estimating the equation is estimated using lag length that minimizes AIC. The null hypothesis is that the series is non stationary (it contains unit roots).The test statistics that is computed needs to be compared critical values that provided in Mackinnon (1991).On other hand, Phillips and Perron (1988) test estimating a non-augmented version of original dickey fuller equation and modifying the t-ratio so that serial correlation does not affect the asymptotic distribution of the test statistics. To conserve space, the results are not reported but can be obtained from the author. Regardless, we found all variables are I(1).

4. Empirical Methodology and Results

4.1 Cointegration Analysis

We start our empirical exercise by first establishing if exports and electricity consumption and real income per capita are cointegrated. Bound testing procedure developed by Pesaran (1995, 1999, and 2001) is used for this purpose. This is considered essential as evidence of cointegrating relationship rules out the possibility of spurious regression. Bound testing procedure performs well in studies that have small sample size. Another interesting fact about this model is that it can estimate long run and short run components of model simultaneously (Narayan and Narayan, 2006). Furthermore, instead of imposing restriction and deciding on the dependent variable, the ARDL method distinguishes between dependent and independent variable through usual F-tests. Furthermore, as noted by Narayan (2004), the unrestricted equilibrium correction model is likely to have superior statistical properties compared to Engle-Granger method, as it does not push short run dynamics into the residual terms (Pattichis 1999; Banerjee *et al.,* 1993; Banerjee *et al.,* 1998). In order to test for cointegration using bounds testing procedure, we firstly estimated the following unrestricted error correction model using ordinary least squares.

$$\Delta In\, Y_t = \alpha + \sum_{i=1}^{n} \beta_i \Delta In\ Y_{t-i} + \sum_{i=1}^{n} \delta_i \Delta In\ E_{t-i} + \sum_{i=1}^{n} \varphi_i \Delta In\ X_{t-i} + \beta_i In\, Y_{t-1} + \delta_i In\, E_{t-1} + \varphi_i In\, X_{t-1} + \varepsilon_t \quad (3)$$

$$\Delta In\, E_t = \alpha + \sum_{i=1}^{n} \beta_i \Delta In\ Y_{t-i} + \sum_{i=1}^{n} \delta_i \Delta In\ E_{t-i} + \sum_{i=1}^{n} \varphi_i \Delta In\ X_{t-i} + \beta_i In\, Y_{t-1} + \delta_i In\, E_{t-1} + \varphi_i In\, X_{t-1} + \varepsilon_t \quad (4)$$

$$\Delta In\, X_t = \alpha + \sum_{i=1}^{n} \beta_i \Delta In\ Y_{t-i} + \sum_{i=1}^{n} \delta_i \Delta In\ E_{t-i} + \sum_{i=1}^{n} \varphi_i \Delta In\ X_{t-i} + \beta_i In\, Y_{t-1} + \delta_i In\, E_{t-1} + \varphi_i In\, X_{t-1} + \varepsilon_t \quad (5)$$

In equations above, Δ is the difference operator; InY_t is logged real income per capita; In E_t is logged Electricity consumption (kWh per capita); In X_t is logged Exports. We then conducted the usual F-test for cointegration .This involves testing the null hypothesis of $H_0 : \beta_i = \delta_i = \varphi_i = 0$ against the alternative hypothesis that atleast one of them is not equal to zero. The computed F-statistics from the test is then compared with critical value from Narayan (2005). If the computed F-statistics exceeds critical value, then the null hypothesis that there is no long run relationship can rejected at 1% significance level. It can note that if the null hypothesis is rejected at 1% significance level, then it will surely be rejected at 5 % and 10% significance level. We used SBC to select the lag length.

Table 2. Bounds test to cointegration

Dependent Variable	Without deterministic trend	With deterministic trend
$F_{stats}(InY_t/InE_t,InX_t)$	7.2834***	5.9974**
$F_{stats}(InE_t/InY_t,InX_t)$	4.2150*	4.1659*
$F_{stats}(InX_t/InE_t,InY_t)$	0.0671	1.6912

NOTE: [a]Critical Values were extracted from Narayan (2005). Table Case II: restricted intercept and no trend, Case IV: Unrestricted intercept and restricted trend.*,** and ***indicates significance at 10% ,5% and 1% respectively .

The F-test is conducted considering all three variables as possible dependent variable .This approach allows us to identify which variable should be the dependent variable should there be a cointegrating relationship. It also allows us to identify the "long run forcing variables". Following Narayan and Smyth (2006), we included trend in the unrestricted error correction model. All the result from F-test is presented in Table 2. We are able to find the evidence of cointegration relationship between the variables when real GDP per capita as well as electricity consumption per capita is considered the dependent variable. Since our objective was to examine cointegration relationship, we do not proceed further except to examine the causal relationship between the three variables.

4.2 Granger Causality Testing

According to Granger (1987), if a pair of I(1) series are cointegrated, then there must a unidirectional causality running in either way. If the exports, electricity consumption and real income per capita are not cointegrated, the causality can be investigated by estimating Vector autoregressive (VAR) in first differences form. However, since the three variables are non-stationary and become stationary after first differencing and are cointegrated, then Granger causality test is conducted with inclusion of lagged error correction term (ECT). This ECT is obtained from the long run relationship. This requires estimating a Vector Error Correction Model as given below.

In equations above, Δ is the difference operator; InY_t is logged real income per capita; In E_t is logged Electricity consumption(kWh per capita); In X_t is logged Exports;ECT_{t-1} is lagged Error Correction term from cointegrating relationship. For the each of the above equation, the change in the dependent variable is caused by its lags as well as previous period's disequilibrium in level, ECT_{t-1} .Given this specification, the presence of short run and long run causality can easily be investigated. We consider the first equation.

$$\Delta InY_t = \alpha + \sum_{i=1}^{\rho} \beta_{ia} \Delta InY_t + \sum_{i=1}^{\rho} \delta_{ib} \Delta InE_t + \sum_{i=1}^{\rho} \varphi_{ic} \Delta InX_t + \lambda_1 ECT_{t-1} + \varepsilon_{1t} \quad (6)$$

$$\Delta InE_t = \alpha + \sum_{i=1}^{\rho} \beta_{id} \Delta InY_t + \sum_{i=1}^{\rho} \delta_{ie} \Delta InE_t + \sum_{i=1}^{\rho} \varphi_{if} \Delta InX_t + \lambda_2 ECT_{t-1} + \varepsilon_{2t} \quad (7)$$

$$\Delta InX_t = \alpha + \sum_{i=1}^{\rho} \beta_{ig} \Delta InY_t + \sum_{i=1}^{\rho} \delta_{ih} \Delta InE_t + \sum_{i=1}^{\rho} \varphi_{ii} \Delta InX_t + \lambda_3 ECT_{t-1} + \varepsilon_{3t} \quad (8)$$

The short-run causal effects can be conducting the F-test of the lagged values of exports and electricity consumption. If exports and electricity consumption are statistically insignificant at say 5% level, then this implied both exports and electricity consumption do not Granger cause GDP per capita in the short run. Furthermore, the statistical significance of ECT_{t-1} implies presence of long run causality running from exports and electricity consumption to GDP per capita in the long run. The coefficient of lagged ECT measures the speed at which dependent variable adjusts to changes in independent variables before converging to its long run level. The estimated coefficient is expected to carry negative sign.

Table 3 shows that in the long run, there is long run causality running from real GDP per capita to electricity consumption per capita at 5% level. In the short run, there is causality running from exports and electricity consumption per capita to real GDP per Capita at 5% and 1% significance level respectively. Furthermore, in the short run, there is causality running from real GDP per capita and electricity consumption per capita to exports at 1% significance level. This is indicative of the fact that there causal impact of electricity consumption on exports. We thus think that any disruption in the electricity service can have a causal impact on exports in the short run only. The results also imply that in the short run causality running from real GDP per capita to electricity consumption at 5%.Our results differ from Narayan and Prasad (2008), who found there is no causality between electricity consumption and economic growth in Japan.

Table 3. Granger causality results

Dependent Variable	Sources of Causation(Independent Variables)			
	Short Run			Long Run
	ΔInY	ΔInX	ΔInE	
ΔInY	-	4.5382(0.604)**	6.473(0.370)***	-0.052[-0.4222]
ΔInX	10.2926(0.113)***	-	9.4998(0.147)***	-
ΔInE	4.0051(0.261)**	2.561(0.464)	-	-0.26755[-2.1322]**

Note: Figures in square brackets are t-statistics, while those in usual brackets are p-values.*** and ** indicates statistical significance at 1% and 5% respectively.

5. Conclusions and Policy Recommendations

In this paper, we have examined the relationship between exports, electricity consumption and real income per capita in Japan using time series data from 1960-2007.Based on our empirical analysis, we are able to find evidence that that exports, electricity consumption and real income per capita are cointegrated. We also found evidence of causality running from real GDP per capita to electricity consumption per capita in the short run as well as in the long run, thus supporting the conservation hypothesis. The government needs to remember the importance of electricity management program to reduce electricity wastage. The government allocates more resources to the development of new sources of energy and ensures sustainability of electricity use. Investment in energy infrastructure is important to avoid adverse effects of electricity crisis on real income per capita. Promoting further competition the electricity industry can reduce cost of electricity and reduce cost of production, fostering more investment in export sector. We hope future research will examine the relationship between electricity consumption and economic growth using other variables, such labor supply or foreign direct investment.

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