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Unveiling Connections among the Export, Electricity and Income in Japan

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Abstract
The extant body of literature pertaining to the interplay among electricity dynamics, export activities, and economic growth yields inconclusive findings. This research endeavors to contribute to this discourse by meticulously scrutinizing the nexus between exports, electricity consumption, and per capita real income in Japan. Leveraging time series data spanning the years 1960 to 2007, our study aims to provide a nuanced understanding of the intricate relationships within this triad and offer valuable insights into the factors influencing Japan's economic landscape during this temporal continuum. Employing the bounds testing procedure formulated by Pesaran et al. (2001, we ascertained the presence of a cointegrating relationship among electricity consumption, exports, and economic growth. Subsequently, upon establishing cointegration, we delved into an examination of the causal dynamics between electricity consumption, exports, and economic growth within the framework of a Vector Error Correction Model. Our findings reveal that over the long term, there exists a causality emanating from both exports and real GDP per capita to electricity consumption. This underscores the intricate interdependencies shaping the relationships among these pivotal economic variables.
Keywords: Exports; Electricity consumption
JEL Codes: Q32, C43

1. INTRODUCTION

Energy security has emerged as a crucial prerequisite for fostering sustainable economic development, prompting numerous nations to enact a range of measures aimed at ensuring reliable energy sources while concurrently mitigating greenhouse gas emissions. Particular attention from the global community is directed toward the Asia Pacific Economic Cooperation (region, which houses some of the world's fastest-growing economies. Within this context, these economies are actively instituting diverse programs designed to enhance energy efficiency and address the imperative challenges associated with energy security. Japan boasts an installed generating capacity of approximately 277.671 gigawatts. The energy matrix comprises contributions from diverse sources, with thermo fuel accounting for 70.5%, hydroelectric power contributing 6.5%, and nuclear power constituting 20.1%, while other sources contribute 2.8% (Energy Data and Modelling Center, 2008). Notwithstanding the limited indigenous energy resources, Japan faces an escalating demand for energy in its commercial, residential, and transportation sectors. This surge in energy consumption can be attributed to a myriad of factors, including evolving lifestyles and an increasing prevalence of vehicle ownership within the country. In contrast to several other nations, including Germany, France, the United States, India, the United Kingdom, China, Canada, and Russia, Japan exhibits a comparatively low energy sufficiency ratio, as reported by the Ministry of Economy, Trade and Industry in 2010. Acknowledging this disparity, the Japanese government has initiated a series of proactive measures aimed at achieving enhanced energy security and concurrently curbing carbon emissions. This strategic approach underscores the nation's commitment to addressing the challenges associated with energy sustainability and environmental responsibility. An illustrative instance of Japan's commitment to bolstering its energy landscape is evident in the enactment of the Basic Law on Energy Policy in 2006. Subsequently, in 2008, the government further fortified its stance by introducing the New National Energy Strategy, a comprehensive framework crafted in response to evolving global developments. Notably, this strategic initiative placed a substantial emphasis on the attainment of energy security, reflecting the government's proactive stance in navigating the challenges and opportunities inherent in the dynamic global energy context. Pursuant to the New National Energy Strategy, the Japanese government outlined ambitious objectives to fortify its energy landscape. These objectives included a targeted improvement of energy efficiency by 30%, a corresponding increase in the share of electric power generated from nuclear energy to a range of 30-40%, a reduction of the oil dependency ratio to approximately 80%, and a proactive elevation of domestic investment in oil exploration and associated development projects. Further demonstrating adaptability, the government introduced significant refinements to the Energy Plan in 2008. Two pivotal principles, "energy-based economic growth" and the "reform of the energy industrial structure," were incorporated into the framework. These additions underscored a dual commitment to fostering economic growth through energy considerations and ushering in transformative changes within the energy sector's structural dynamics. The incorporation of the new principles, "energy-based economic growth" and the "reform of the energy industrial structure," builds upon

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the pre-existing foundations of energy security, economic efficiency, and environmental suitability. The Revised Strategic Energy Plan delineates a set of ambitious targets for the year 2030. These objectives encompass the doubling of the energy self-sufficiency ratio and energy independence ratio to 36% and 70%, respectively. Additionally, the plan aims to reduce carbon emissions from the residential sector by 50%, alongside endeavors to augment energy efficiency within the industrial sector. It is noteworthy that Japan's electricity prices have consistently ranked among the highest in developed countries. This circumstance has spurred a series of reforms within the electricity sector. A prior study by the OECD (1998) identified Japan as having the highest electricity prices within the OECD, providing context for the ongoing efforts to address and rectify this economic aspect.

Table 1: Electricity Power Consumption 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

Table 1 provides a comparative analysis of electricity power consumption among selected Asian countries. Notably, Japan's electricity power consumption stands out as relatively high when contrasted with other major economies such as India and China. This observation underscores the imperative for the Japanese government to formulate strategic policies aimed at curtailing electricity wastage and fostering investment in alternative sources of electricity generation. Furthermore, the recent seismic damage to nuclear power plants has introduced a significant element of vulnerability, potentially exerting considerable pressure on Japan's economic growth trajectory. In light of these challenges, it becomes paramount for the government to swiftly implement policies addressing any potential energy crisis, thereby safeguarding the nation's export sector from adverse impacts. Urgent and decisive actions are essential to mitigate risks and ensure the sustained resilience of Japan's economy in the face of evolving energy dynamics. As of Thomas's analysis in 2006, the electricity industry in Japan operates under the control of 10 vertically integrated regional companies, with Tokyo Electric and Kansai Power holding dominant positions. Despite government efforts to liberalize the industry, the anticipated transformative impact is yet to be fully realized. The persisting structure poses a potential risk, as any prospective electricity shortage could lead to significant disruptions in the production of goods within the export sector, potentially hampering overall economic performance. Addressing this structural limitation and fostering greater resilience in the electricity sector remains a crucial agenda for ensuring the stability and vitality of Japan's economic activities. Nuclear power plants have played a pivotal role in Japan's electricity generation landscape. Despite safety concerns associated with this form of power production, nuclear energy holds significance due to its minimal greenhouse gas emissions, making it a crucial tool for addressing energy supply stability, environmental preservation, and economic efficiency. Recognizing its multifaceted contributions, nuclear energy has attained recognition as a key component within Japan's energy strategy. In fact, the promotion of nuclear energy stands as one of the pillars in Japan's comprehensive Energy Plan, reflecting its integral role in the nation's pursuit of a sustainable, environmentally conscious, and economically efficient energy future. he recent earthquake has brought forth concerns regarding the safety implications associated with nuclear energy, underscoring the need for policies promoting such forms of energy to equally prioritize their socio-economic effects. The aftermath of the recent natural disaster in Japan, which garnered global attention, is yet to fully manifest its impact on the Japanese economy, neighbouring Asian economies, and other developed nations. Assertions about the strength of the Japanese economy and its ability to rebound swiftly are subject to empirical scrutiny, emphasizing the importance of evaluating such statements based on concrete evidence rather than mere conviction. According to a report from the IMF in 2011, there is a cautionary note regarding the potential impact on neighbouring Asian economies through trade channels due to the recent events in Japan. The significant damage to nuclear power plants, crucial for electricity generation in Japan, underscores the importance of comprehending the intricate relationship between electricity consumption and economic growth in the aftermath of such disruptive occurrences. The repercussions on trade and energy dynamics among neighbouring nations further emphasize the need for a nuanced examination of these interdependencies to inform effective policy responses and mitigate potential economic challenges. Pprimarily focused on establishing the relationship between electricity consumption and economic growth through bivariate regression analyses. In the work conducted by Wolde-Rufael in 2009, it was discovered that the causality results for numerous African countries underwent alterations when additional variables, such as capital and labor, were incorporated into the analysis. This observation underscores the importance of considering a more comprehensive set of factors in understanding the intricate dynamics between electricity consumption and economic growth, highlighting the need for a multivariate approach to capture the nuanced relationships at play.

The ongoing debate surrounding the significance of electricity for economic growth persists, possibly stemming from the historical tendency of earlier studies to investigate cointegration and causality within a bivariate framework. This

limitation may contribute to the current ambiguity in understanding the precise role of electricity in economic growth. In our present study, we deliberately extend the analysis to encompass a more comprehensive framework by incorporating exports as an additional variable. Recognizing the pivotal role exports play in economic dynamics, our investigation aims to elucidate the nuanced relationship between electricity consumption and economic growth, considering the potential influence of electricity on the performance of the export sector. Through this expanded analytical approach, we seek to contribute valuable insights to the ongoing discourse surrounding the intricate connections between energy consumption, economic growth, and international trade. This paper pursues a twofold objective. Firstly, our aim is to determine whether the three variables under consideration are cointegrated, indicating a shared movement in the long run. This objective holds significance in the context of recent advancements in cointegration literature. Unraveling whether electricity consumption and real income per capita exhibit a common long-term trend is of particular interest, providing valuable insights into the intertwined dynamics of these variables and contributing to the ongoing discourse on their co-movement over extended periods. Secondly, our investigation delves into the causal relationships among exports, electricity consumption, and economic growth within the framework of a Vector Error Correction Model. The inclusion of exports as an additional variable in the analysis is anticipated to provide a more comprehensive understanding of the causal dynamics between electricity consumption and economic growth. If a unidirectional causality is observed from electricity consumption to economic growth, it would lend support to the growth hypothesis, suggesting a significant direct influence of electricity consumption on economic growth. This nuanced examination aims to contribute to a refined understanding of the intricate interactions among these variables, shedding light on the specific pathways through which electricity consumption may impact economic growth. Therefore, policies aimed at diminishing electricity consumption may exert adverse effects on economic growth if a unidirectional causality from electricity consumption to economic growth is established, supporting the growth hypothesis. Conversely, if evidence indicates a unidirectional causality from economic growth to electricity consumption, endorsing the conservation hypothesis, policies designed to reduce electricity consumption would not be expected to have detrimental impacts on economic growth. The presence of bidirectional causality between electricity consumption and economic growth aligns with the feedback hypothesis. In such a scenario, policies seeking to curtail electricity consumption may negatively impact economic growth, and these economic fluctuations could, in turn, feed back into influencing electricity consumption. Understanding the nature of these causal relationships is crucial for formulating effective policies that balance the objectives of energy conservation and sustained economic growth.

In conclusion, in the absence of causality between electricity consumption and economic growth, it implies that policies focused on electricity conservation would not have an impact on economic growth. These insights hold relevance for policymakers in both the trade and energy sectors.

2. LITERATURE REVIEW

Payne's (2010) comprehensive survey of the literature regarding the causal relationship between electricity consumption and economic growth reveals a mixed body of evidence. His analysis discerns that various studies present divergent perspectives on this relationship: 31.15% of the studies endorse the neutrality hypothesis, 27.87% support the conservation hypothesis, 22.95% align with the growth hypothesis, and 18.03% substantiate the feedback hypothesis. These findings underscore the complexity and variability in the observed relationships between electricity consumption and economic growth, highlighting the nuanced nature of this crucial interplay in economic dynamics.

The study conducted by Narayan and Singh (2007) in Fiji indicates that electricity consumption, employment, and real GDP are cointegrated, suggesting a shared long-term relationship among these variables. Similarly, Ho and Siu (2007) observed a long-run relationship between electricity consumption and GDP for Hong Kong. Their findings imply a sustained connection between these two economic factors over an extended period. In the case of Bangladesh, Mozumder and Marathe (2007) identified a unidirectional causality from per capita GDP to per capita electricity consumption. This implies that economic growth, as measured by per capita GDP, influences the consumption of electricity in the country, supporting a specific directionality in the relationship between these variables. These studies contribute valuable insights to the broader understanding of the connections between electricity consumption and economic indicators in diverse economic contexts. The study conducted by Yoo (2006) did not find evidence of cointegration between electricity consumption and economic growth in ASEAN countries, suggesting that there might not be a long-term shared relationship between these variables in the context of those nations. On the other hand, Altinay and Karagol (2005) observed evidence of a unidirectional causality running from electricity consumption to GDP for Turkey. This implies that in Turkey, electricity consumption influences economic growth, supporting the idea that energy consumption plays a significant role in driving economic activity in the country. These diverse findings underscore the importance of considering regional and country-specific contexts when examining the relationship between electricity consumption and economic growth. The heterogeneity in results highlights the complex and multifaceted nature of this relationship, subject to various factors and dynamics in different geographical and economic settings.

Lee and Chang's study in 2005 reveals similar evidence for Taiwan, indicating a specific relationship between electricity consumption and economic factors in that region. Narayan and Smyth's (2005) findings suggest cointegration among electricity consumption, employment, and real income, implying a shared long-term relationship among these variables. In contrast, other studies present evidence of unidirectional causality running from economic growth to electricity consumption. For instance, Ghosh (2002) found such evidence for India, indicating that economic growth influences electricity consumption in the Indian context. Similarly, Hatemi and Irandoust (2005) observed

unidirectional causality from economic growth to electricity consumption in Sweden. These diverse outcomes underscore the need for nuanced analyses and consideration of specific contextual factors when examining the causal relationships between electricity consumption and economic variables across different countries and regions. Indeed, the study conducted by Shiu and Lam in 2004 revealed that electricity consumption and economic growth in China are cointegrated. This implies the existence of a shared long-term relationship between the two variables. Such findings contribute valuable insights into the sustained connection between electricity consumption and economic growth in the Chinese context, shedding light on the intertwined dynamics of these crucial economic factors over an extended period. Certainly, Yuan et al.'s study in 2007 identified evidence of cointegration between electricity consumption and economic growth. This underscores the presence of a sustained relationship between these two variables over the long term. Such findings contribute to the broader understanding of the interconnected dynamics between electricity consumption and economic growth, providing valuable insights into their enduring association in the context examined by Yuan and colleagues. Indeed, Wolde-Rufael's study in 2006 generated mixed evidence concerning the causal relationship between electricity consumption and real GDP per capita. This underscores the intricate and variable nature of the observed relationships, emphasizing that the causal dynamics between electricity consumption and economic variables can be nuanced and contingent on specific contextual factors. Such nuanced findings highlight the importance of considering various elements when examining the intricate interactions between electricity consumption and economic variables. Certainly, the collective body of studies discussed contributes significantly to the evolving understanding of the interplay between electricity consumption and economic growth. The diverse findings from these studies underscore the need for detailed examinations in various contexts, reflecting the intricacies and complexities inherent in the relationship between electricity consumption and economic variables. This nuanced perspective is crucial for policymakers, researchers, and practitioners seeking to formulate effective strategies and interventions, as it emphasizes the importance of context-specific considerations in comprehending the dynamics of energy consumption and its impact on economic growth. Squalli's study in 2007 makes noteworthy contributions to the understanding of the relationship between electricity consumption and economic growth, particularly for the Organization of Petroleum Exporting Countries (OPEC). The findings reveal evidence of a long-run relationship between electricity consumption and economic growth for all OPEC nations, as determined through bound tests. Additionally, Squalli identifies the significance of electricity consumption for economic growth in specific countries, including Indonesia, Iran, Nigeria, Qatar, and Venezuela. These insights underscore the varying impacts and importance of electricity consumption on economic dynamics across different regions and nations within the OPEC framework.

3. DATA SOURCES AND UNIT ROOTS TESTS

In our study, data was obtained from the World Development Indicators (2008). To address potential issues of heteroscedasticity and facilitate elasticity calculations, all variables were transformed using natural logarithms. The three key variables under consideration were real income per capita, electricity consumption (measured in kilowatt-hours per capita), and exports. The dataset spans the period from 1960 to 2007. Our analysis commenced with an examination of the unit root properties of the data series, a crucial step in understanding the stationarity of the variables over time. This preliminary assessment lays the foundation for subsequent statistical analyses and ensures the robustness of our empirical investigation. The concept of stationarity is crucial in time series analysis, where a series is considered stationary if it exhibits a constant mean, variance, and autocovariance over time. Despite the bound testing procedure not necessitating pretesting for unit root, it's essential to note that for conducting Granger Causality tests, the variables must be integrated of order 1, denoted as I(1). In the context of nonstationary time series, regressing one nonstationary time series on another might result in a spurious regression, where statistical relationships may arise by chance rather than reflecting meaningful underlying patterns. However, it is important to acknowledge that if there exists a long-run relationship between the variables, such a regression may not be spurious but instead could capture meaningful and sustainable associations. The careful consideration of unit root properties and the potential for cointegration is vital in distinguishing between spurious and meaningful relationships in nonstationary time series analysis. Certainly, despite the potential for meaningful relationships in nonstationary time series, it is crucial to conduct unit root tests to determine the stationary properties and ascertain that the variables are not integrated of order 2, denoted as I(2). The Augmented Dickey-Fuller (ADF) test, commonly employed in such analyses, corrects for higher-order serial correlation through lagged difference terms. It's worth noting that the Phillips-Perron test provides a non-parametric correction for residual serial correlation. Monte Carlo studies, such as those conducted by Banerjee et al. (1993) and Choi (1992), have indicated that the Phillips-Perron test exhibits greater statistical power compared to the standard ADF test. This emphasizes the importance of selecting robust unit root tests to ensure accurate assessments of stationarity and support reliable subsequent analyses, including Granger Causality tests.

4. EMPIRICAL METHODOLOGY AND RESULTS

In our empirical analysis, we initiate by determining whether exports, electricity consumption, and real income per capita are cointegrated. To accomplish this, we employ the bound testing procedure developed by Pesaran (1995, 1999, and 2001). This methodology is crucial as it helps rule out the possibility of a spurious regression, particularly important when examining relationships between variables over time. The choice of the bound testing procedure is justified by its robust performance in studies with small sample sizes. An additional advantage of this model is its capability to estimate both long-run and short-run components of the model simultaneously, as highlighted by Narayan and Narayan (2006). This feature enhances our ability to capture and understand the dynamics of the relationships

between exports, electricity consumption, and real income per capita over different time horizons. The ARDL (Autoregressive Distributed Lag) method, as opposed to imposing restrictions and designating a dependent variable, differentiates between dependent and independent variables through conventional F-tests. This approach is advantageous as it allows for a more flexible modeling structure. Additionally, as highlighted by Narayan (2004), the unrestricted equilibrium correction model within the ARDL framework is likely to exhibit superior statistical properties compared to the Engle-Granger method. This superiority arises because the ARDL method avoids pushing short-run dynamics into the residual terms, as observed in the Engle-Granger method, leading to more accurate estimations (Pattichis 1999; Banerjee et al., 1993; Banerjee et al., 1998). To conduct the bounds testing procedure for cointegration, we initially estimated the unrestricted error correction model using ordinary least squares. This methodological approach ensures a comprehensive examination of the relationships between the variables while considering both short-run and long-run dynamics.

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

The F-test is employed by considering all three variables as potential dependent variables, allowing us to discern which variable should be designated as the dependent variable in the presence of a cointegrating relationship. This approach aids in identifying the "long run forcing variables," shedding light on the key drivers of the cointegrating relationship. Consistent with the methodology proposed by Narayan and Smyth (2006), we incorporated a trend in the unrestricted error correction model to enhance the analytical framework. The results of the F-test are presented comprehensively in Table 2. Notably, evidence of a cointegrating relationship between the variables is found when considering real GDP per capita and electricity consumption per capita as the dependent variables. This empirical outcome signifies a shared long-term association among these key economic variables, paving the way for further investigation into their interdependencies.

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]**

Given our objective of examining cointegration relationships, we refrain from further analysis, focusing instead on investigating the causal relationships among the three variables. In accordance with Granger (1987), when a pair of I(1) series are cointegrated, there must be a unidirectional causality running in either direction. If exports, electricity consumption, and real income per capita are not cointegrated, causality can be explored by estimating a Vector Autoregressive model in first differences form. However, since the three variables are non-stationary and become stationary after first differencing and are cointegrated, we proceed with the Granger causality test, incorporating a lagged error correction term obtained from the long-run relationship. This ECT serves as a crucial component in capturing the dynamic causal relationships between the variables. Table 3 reveals that in the long run, there is a causality running from real GDP per capita to electricity consumption per capita at a 5% significance 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 levels, respectively. Additionally, in the short run, there is causality running from real GDP per capita and electricity consumption per capita to exports at a 1% significance level. This indicates a causal impact of electricity consumption on exports, highlighting the dynamic relationships and interdependencies among these key economic variables. Therefore, we posit that any disruption in electricity service can exert a causal impact on exports, but this effect is observed only in the short run. Furthermore, the results suggest that in the short run, there is a causality running from real GDP per capita to electricity consumption at a 5% significance level. It's notable that our findings differ from those of Narayan and Prasad (2008), who reported no causality between electricity consumption and economic growth in Japan. These discrepancies could be attributed to variations in the time periods, data sources, or methodological approaches employed in the respective studies. The nuanced nature of the relationship between electricity consumption and economic variables may manifest differently under different circumstances and analytical frameworks.

5. CONCLUSION

In this study, we conducted a comprehensive examination of the relationship between exports, electricity consumption, and real income per capita in Japan, utilizing time series data spanning from 1960 to 2007. Our empirical analysis has yielded compelling evidence supporting the existence of a cointegrated relationship among exports, electricity consumption, and real income per capita in the Japanese context. This finding suggests a shared long-term association among these crucial economic variables, contributing valuable insights to the understanding of the dynamics within Japan's economic landscape. Additionally, our analysis revealed compelling evidence of causality running from real GDP per capita to electricity consumption per capita, both in the short run and the long run. This finding supports the conservation hypothesis, emphasizing the significance of efficient electricity management programs. It underscores the importance for the government to prioritize initiatives aimed at reducing electricity wastage, aligning with sustainable and efficient resource utilization practices for long-term economic and environmental benefits. Given the evidence of causality from real GDP per capita to electricity consumption per capita, both in the short run and long run, supporting the conservation hypothesis, it becomes imperative for the government to strategically allocate resources towards the development of new energy sources and ensure the sustainability of electricity use. Investing in robust energy infrastructure is crucial to mitigate potential adverse effects of an electricity crisis on real income per capita. This strategic approach aligns with the goal of enhancing energy security, promoting economic stability, and fostering sustainable development in the long term. Given the evidence of causality from real GDP per capita to electricity consumption per capita, both in the short run and long run, supporting the conservation hypothesis, it becomes imperative for the government to strategically allocate resources towards the development of new energy sources and ensure the sustainability of electricity use. Investing in robust energy infrastructure is crucial to mitigate potential adverse effects of an electricity crisis on real income per capita. This strategic approach aligns with the goal of enhancing energy security, promoting economic stability, and fostering sustainable development in the long term.

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