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Assessing the Stationarity of Per Capita Electricity Consumption: Time Series Analysis in ASEAN Countries

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ABSTRACT

The stationarity of per capita electricity consumption has become a critical subject of research and policy consideration, with a wealth of literature exploring this aspect using diverse methodologies. This paper, however, differentiates itself by focusing exclusively on electricity consumption, a pivotal energy form, within the context of the ASEAN region. The stationarity or nonstationarity of electricity consumption has significant implications for energy management and policy formulation. A Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test with structural breaks was applied to data spanning from 1971 to 2014 for nine ASEAN nations, shedding light on distinct patterns. The majority of countries, including Indonesia, Thailand, Singapore, Vietnam, Malaysia, the Philippines, Myanmar, and Cambodia, exhibited nonstationary electricity consumption, suggesting susceptibility to prolonged fluctuations influenced by various structural factors. In contrast, Brunei displayed stationary electricity consumption, implying temporary effects of energy demand shocks. The policy implications are substantial. Nonstationary countries require flexible energy policies that address both immediate and long-term fluctuations in electricity consumption, especially in sectors like manufacturing, healthcare, and education, heavily reliant on electricity. Conversely, stable countries like Brunei should continuously monitor energy trends to make proactive policy adjustments.

Keywords: Electricity Consumption, Structural Break, Unit Root, ASEAN
JEL Classifications: C22, Q41, Q43

1. INTRODUCTION

The investigation into the stationarity of per capita energy consumption has garnered substantial attention in the academic sphere, with an ever-expanding body of literature employing a diverse array of methodological approaches. Previous scholarly contributions, such as those by Chen and Lee (2007), Kula et al. (2012), Ozcan and Ozturk (2016), Magazzino (2016), Mishra et al. (2009), Hasanov and Telatar (2011), Bolat et al. (2013), and Shahbaz et al. (2013), have ventured into this realm. As the global community faces increasing energy-related challenges, the analysis of time series characteristics in per capita energy consumption becomes exceptionally important, not only for researchers but also for policymakers.

The existence of a unit root in per capita energy consumption is highly significant. When per capita energy consumption displays unit root attributes, it signifies that it does not spontaneously revert to its balanced state following a disturbance (Kula et al., 2012). Instead, disturbances in per capita energy consumption persist, raising questions about the resilience of the energy sector. Conversely, if per capita energy consumption follows a stationary pattern, shock impacts are short-lived, allowing for the prediction of future energy consumption patterns based on historical trends. This distinction between stationary and non-stationary energy consumption dynamics profoundly shapes our understanding of the dynamics of the energy sector. Additionally, the determination of energy consumption stationarity has far-reaching implications. It affects policymakers, as stationary energy consumption implies that shocks have temporary effects on economic activity, suggesting caution in implementing policies that disrupt the energy-economic growth relationship. This understanding is particularly vital in the context of models such as ARIMA, where stationarity is a fundamental requirement for meaningful predictions (Parreño, 2022c; Parreño, 2023). Conversely, non-stationary energy consumption leads to lasting shocks, necessitating more resilient policies (Shahbaz et al., 2013; Magazzino, 2016). Furthermore, the interconnectedness between the energy sector and other economic domains is crucial, as enduring energy consumption shocks can affect multiple sectors and macroeconomic aggregates (Apergis et al., 2010; Aslan, 2011; Mishra et al., 2009; Shahbaz et al., 2013; Smyth, 2013). Moreover, the issue on energy consumption stationarity influences modeling efforts. The policy implications of the causal relationship between energy consumption and real output depend on its direction. If the causal relationship is unidirectional, it indicates that reducing energy usage might lead to potential income reductions. Energy price dynamics, particularly whether they are mean-reverting or follow a random walk, have significant implications for financial investors. Mean-reverting prices aid in forecasting future price movements based on historical behavior, while random walk prices pose challenges for predictions. Thus, producers who rely on energy as an input need to understand energy price dynamics to optimize their operational strategies (Mishra et al., 2009; Ozturk and Aslan, 2011; Shahbaz et al., 2014).

The prevailing consensus in much of the extant literature, when examining the stationarity and non-stationarity of energy consumption, leans towards non-stationarity, particularly when structural breaks are not considered (Al-Iriani, 2006; Narayan and Smyth, 2003; Narayan and Popp, 2012; Belke et al., 2011, Parreño, 2022a; Parreño, 2022b). However, a nuanced perspective emerges when structural breaks are meticulously integrated into the analysis. In such instances, a significant proportion of studies demonstrate that per capita energy consumption is, in fact, stationary, shedding light on the potential impacts of structural changes in energy markets on the stationarity of this critical metric. Incorporating these structural breaks into the analysis markedly enhances the statistical power of unit root tests, offering a more comprehensive understanding of the dynamic behavior of energy consumption (Zachariadis and Pashourtidou, 2007; Apergis et al., 2010; Aslan and Kum, 2011; Ozturk and Aslan, 2011; Kula et al., 2012; Shahbaz et al., 2013; Bolat et al., 2013).

While previous investigations have predominantly focused on overall energy consumption, this study seeks to establish a distinct niche by concentrating exclusively on electricity consumption. Electricity, as a pivotal energy form with widespread implications for economic and societal functions globally (Dye, 2023), warrants dedicated examination regarding its per capita consumption stationarity. Electricity is not only a fundamental energy source but also a linchpin of modern life. It powers industries, homes, and essential infrastructure, and its availability and stability are critical for economic development and the quality of life (Zohuri, 2015; Gumaru et al., 2019). Furthermore, as the world grapples with environmental concerns and the transition to cleaner energy sources, the study of electricity consumption becomes even more vital. The stability of per capita electricity consumption directly affects the robustness and sustainability of energy systems, as well as the formulation of policies to guarantee a steady and effective electricity provision (Jacobsson and Lauber, 2006; Jacobson et al., 2015; Gielen et al., 2019).

It is important to note that prior studies primarily centered on OECD (Kula et al., 2012; Aydin, 2019; Husein and Kara, 2023), EMU (Magazzino, 2016), and other developed nations (Lee and Chang, 2008; Shahbaz et al., 2013; Akram et al., 2019; Aydin and Pata, 2020). This limited scope introduced a critical research gap, as it failed to encompass the unique dynamics of electricity consumption in the diverse context of ASEAN countries. It is crucial to recognize that the energy dynamics in this region differ significantly from those in more developed nations. The ASEAN countries encompass a diverse range of economies, from emerging markets to rapidly industrializing nations (Kawai and Wignaraja, 2011; Peimani, 2013; Sovacool and Drupady, 2016; Mochizuki and Ollapally, 2016). Within this context, it is significant to emphasize that, to date, no empirical effort has been undertaken to scrutinize the stationarity attributes of per capita electricity consumption within the ASEAN countries. Our research seeks to address this gap in the existing body of knowledge by investigating the stationarity of per capita electricity consumption in the ASEAN region. In pursuit of this objective, our methodology incorporates Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test with structural breaks. We apply this analytical tool across a diverse spectrum of 10 ASEAN nations, encompassing an extensive time span from 1971 to 2014. This extensive dataset enables a thorough examination of the temporal dynamics characterizing per capita electricity consumption within the ASEAN region.

2. MATERIALS AND METHODS

2.1. The Data

The primary data source for this study was the electric power consumption (kWh per capita) dataset, acquired from the World Development Indicator database, maintained by the World Bank. This dataset provides comprehensive information on electric power consumption per capita and spans the period from 1971 to 2014, with the exception of Cambodia, whose data span only from 1995 to 2014. The study encompasses nine ASEAN countries: Indonesia, Thailand, Singapore, Vietnam, Malaysia, the Philippines, Myanmar, Cambodia, and Brunei Darussalam. This subset of countries was chosen based on data availability. Lao PDR was not included in the study since there was no available data. Table 1 offers a comprehensive summary of per capita electric power consumption statistics across several ASEAN countries. The Jarque-Bera statistics indicate that Vietnam and Myanmar deviate from a normal distribution (at a 5% significance level). The statistics for skewness and kurtosis corroborate the findings of the Jarque-Bera test.

2.2. Kwiatkowski-Phillips-Schmidt-Shin Unit Root Test

In this study, we employed the KPSS unit root test with structural breaks, a method introduced by Carrion-i Silvestre et al. (2005) and Carrion-i Silvestre (2005), to evaluate the presence of a unit root in electricity consumption data. The primary reason for choosing the KPSS test in this context is its ability to distinguish between

Table 1: Summary statistics

ASEAN	Mean	SD	Skewness	Kurtosis	Jarque-Bera (prob. >χ^2)
Indonesia	272.24752	240.44695	0.65087967	2.215172	0.1203
Thailand	1077.74519	783.10403	0.34962359	1.691212	0.1329
Singapore	5379.07693	2649.98985	−0.10001688	1.512709	0.1269
Vietnam	326.30091	393.83038	1.44562973	3.855189	0.0000*
Malaysia	1910.09888	1314.59504	0.47911928	1.918758	0.1476
Philippines	431.48953	129.19802	0.51958225	1.938905	0.1324
Myanmar	65.32115	45.48099	1.71131200	5.675617	0.0000*
Cambodia	92.04378	75.61551	0.98545634	2.893917	0.1973
Brunei Darussalam	5314.49348	2906.48772	-0.01493328	1.500638	0.1273

*P<0.05

stationary and non-stationary time series data. Unlike other unit root tests, such as the Augmented Dickey-Fuller (ADF) test, the KPSS test is designed to identify stationarity in cases where a series may have a non-zero mean and non-constant variance. Further, unlike traditional unit root tests, this approach accounts for multiple structural breaks that may influence both individual effects and the time trend within the time series data. The KPSS test with structural breaks is formulated as follows:

$$y_{it} = \alpha_i + \beta_i t + \sum_{\{k=1\}}^{m} \left(b_{ik} t - D_{TB_{ik}t} + D_{U_{ik}t} \right) + \varepsilon_{it} \quad (4)$$

In this formulation: y_{it} represents the time series data for the i^{th} individual at time t; αι and β_i are individual-specific intercept and slope coefficients, respectively; $b_{ik}\ t$ represents the kth break date for the i^{th} individual; and $D_{TB_{ik}t}$ and D_{ik^t} are dummy variables representing structural breaks in the level and slope of the time series data, respectively. The number of structural break points, represented as m is computed using the LWZ (Liu et al., 1997) information criteria, permitting up to five potential structural breaks. The estimation of the long-run variance utilizes the Bartlett kernel with automatic spectral window bandwidth selection, following the approach outlined by Sul et al. (2005). The KPSS unit root test assesses the null hypothesis of stationarity against the alternative hypothesis of a unit root. The test statistic, denoted as LM, is calculated as follows:

$$LM = \frac{\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{S}_{it}}{\lambda \omega} \quad (5)$$

Where N represents the number of individuals; T is the total number of time periods; and signifies the estimated residual from the regression model.

3. RESULTS AND DISCUSSION

Table 1 presents summary statistics for per capita electricity consumption in various ASEAN countries, offering valuable insights into consumption patterns. Mean consumption levels exhibit significant variations, with Brunei Darussalam and Singapore demonstrating notably high per capita consumption, contrasting with Cambodia and Myanmar, which have significantly lower levels. These differences may be attributed to disparities in economic development, population size, and the prevalence of energy-intensive industries. Additionally, the higher levels of electricity consumption in Brunei can be attributed to the generous subsidies on electricity tariffs enjoyed by residents, potentially resulting in increased electricity usage beyond essential needs (Ahmad, 2014). The standard deviation values reflect the degree of variation in consumption. Singapore and Brunei Darussalam have relatively low standard deviations, indicating more consistent consumption levels, while Indonesia and Vietnam exhibit higher variability, possibly due to differences in geography, urbanization, and access to electricity infrastructure. Positive skewness in Vietnam and Myanmar suggests an asymmetric distribution, indicating that some segments of the population consume less electricity while others consume significantly more. Income inequality and variations in urbanization can play a role in this phenomenon. Kurtosis measures the tails of the distribution, and positive kurtosis in Vietnam and Myanmar signifies heavy tails with more extreme values. This could be influenced by challenges related to rural electrification, inconsistent electricity supply, and the presence of energy-intensive industries in specific regions. Additionally, the Jarque-Bera test results indicate that Vietnam and Myanmar have non-normally distributed consumption patterns, potentially stemming from regional disparities in electricity access and consumption across sectors.

Figure 1 shows the evolution of electric power consumption per capita in nine different ASEAN nations from 1971 to 2014. Among the countries, Indonesia displayed a noticeable increase in consumption, particularly from the 1990s, and by 2014, it had reached approximately 808.42 kWh per capita. Thailand, too, exhibited a steady rise in consumption, with the figure standing at approximately 2483.56 kWh per capita in 2014. Singapore, in contrast, consistently maintained a high level of consumption, reaching about 8844.69 kWh per capita by 2014. Vietnam experienced gradual growth, more pronounced in the late 1990s, culminating in approximately 1431.16 kWh per capita in 2014. Malaysia also saw steady growth, with 4539.50 kWh per capita in 2014. The Philippines, Myanmar, and Cambodia showed increasing trends in power consumption, and in 2014, they were at approximately 690.77 kWh, 220.39 kWh, and 272.50 kWh per capita, respectively. Brunei Darussalam consistently had a high consumption rate, reaching around 10121.06 kWh per capita in 2014. It can also be noticed that Singapore and Brunei were the highest consumers while Cambodia was the lowest.

Following the study of Bolat et al. (2013), we determined the number of breakpoints and their corresponding dates and then applied the KPSS test. We used the LWZ information criteria to determine the number of structural breaks and applied Zivot-Andrews test to identify specific dates. Analysis of structural breaks in the time series data, as presented in Table 2, unveils intriguing patterns among ASEAN countries. Firstly, several countries, including Indonesia, Thailand, and Malaysia, have experienced structural breaks around the late 1990s to early 2000s, with break years spanning 1995 to 2002. These years coincide with a period of regional economic instability, particularly the Asian Financial Crisis of 1997 (Kim and Haque, 2001). Economic shocks during this period might have influenced changes in electricity consumption, explaining the structural breaks observed. In contrast, countries like Cambodia and Vietnam have structural breaks extending from the early to mid-2000s, ranging from 2001 to 2008. These dates are relatively later than the aforementioned group, potentially indicating differences in their economic development and industrialization. These nations may have experienced rapid growth and urbanization during this period, contributing to shifts in electricity consumption (Henderson, 2005). In contrast, Myanmar reveals fewer structural breaks (only two) and more recent dates, starting in 1993 and extending to 2008. These dates could be linked to the unique political and economic context of the country, which experienced significant changes during this period (Jones, 2014). Brunei, on the other hand, demonstrates stationary electricity consumption and a different pattern. With structural breaks from 1980 to 2002, the electricity consumption of this country exhibits a degree of stability compared to its regional counterparts (Ahmad, 2014). Furthermore, many of the ASEAN countries included in the study share a common occurrence of structural breaks around the year 2002. This synchronicity raises intriguing questions, as it corresponds with a series of significant global events, particularly the tragic events of September 11, 2001, in the United States. The consequences of the 9/11 attacks, with their far-reaching implications, are likely to have impacted world economic activity and energy supply dynamics on a global scale (Shahbaz et al., 2014). This global context introduces an additional layer of complexity to the structural break patterns observed, highlighting the interconnectedness of international events and their potential to shape energy consumption dynamics at both national and regional levels. Finally, the most recent break dates align with the onset of the global economic crisis that commenced in 2008.

Figure 1: Time series plot of electricity consumption of ASEAN countries

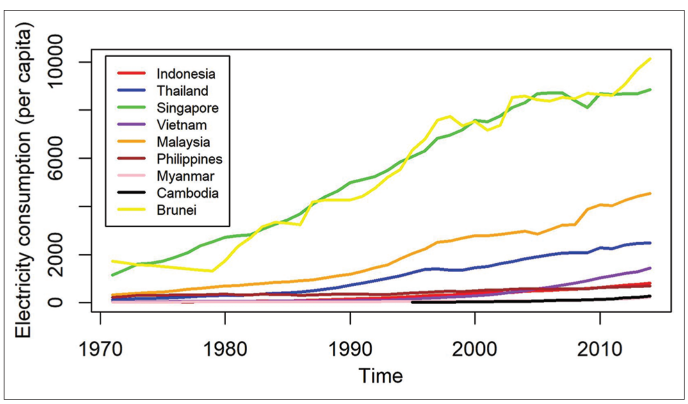

Table 2 displays the results of the KPSS tests conducted for individual ASEAN countries to assess the stationarity of per capita electricity consumption, which carries vital implications for energy management policies. These tests determine whether energy demand shocks have enduring or temporary effects. In most cases, the null hypothesis of stationarity is rejected, indicating nonstationary electricity consumption patterns in Indonesia, Thailand, Singapore, Vietnam, Malaysia, the Philippines, Myanmar, and Cambodia. This suggests that these countries are susceptible to prolonged fluctuations influenced by structural factors. Consequently, it is imperative to develop resilient energy management strategies to address these persistent variations. Notably, Brunei is an exception where per capita electricity consumption is stationary. This implies that energy demand shocks in Brunei have temporary effects, and energy policies are expected to have a transient impact on consumption patterns. Shahbaz et al. (2014) support these findings, affirming that Indonesia, Malaysia, the Philippines, Thailand, and Vietnam exhibit unit roots, indicative of nonstationary energy consumption. Policymakers in these nations must craft adaptive energy policies that address both immediate needs and the long-term nonstationary nature of energy consumption. Implementing flexible approaches capable of dynamically responding to the evolving energy landscape is paramount.

When comparing to other studies, we found that there are differences in results between the ASEAN countries and more developed regions, such as the OECD and EU. We observed that the ASEAN are nonstationary, while those in OECD, EU, and other developed nations are stationary (Kula et al., 2012; Magazzino, 2016; Shahbaz et al., 2014). The observed differences reflect a complex interplay of socio-economic, developmental, and structural factors. Firstly, many ASEAN nations are still in the process of industrialization and economic growth, which is

Table 2: Individual KPSS unit root test results for ASEAN countries

Countries	KPSS test	*m*	Time of structural breaks				Critical values		Result
			$T_{b,1}$	$T_{b,2}$	$T_{b,3}$	$T_{b,4}$	0.90	0.95	
Indonesia	0.2947**	4	1988	1995	2002	2008	0.119	0.146	Nonstationary
Thailand	0.2479**	4	1988	1994	2002	2008	0.119	0.146	Nonstationary
Singapore	0.1625**	4	1978	1987	1995	2002	0.119	0.146	Nonstationary
Vietnam	0.2881**	3	1995	2002	2008		0.119	0.146	Nonstationary
Malaysia	0.2367**	4	1980	1990	1996	2008	0.119	0.146	Nonstationary
Philippines	0.2494**	4	1976	1995	2002	2008	0.119	0.146	Nonstationary
Myanmar	0.2240**	2	1993	2008			0.119	0.146	Nonstationary
Cambodia	0.2000**	4	2001	2005	2008	2011	0.119	0.146	Nonstationary
Brunei	0.1143	4	1980	1986	1994	2002	0.119	0.146	Stationary

**significant at 10% and 5% levels

often accompanied by a surge in electricity usage. In contrast, the OECD and EU member countries have largely transitioned to more service-based and technologically advanced economies, resulting in a relatively stable and even declining trend in per capita electricity consumption (Hasanov and Telatar, 2011). Furthermore, the urbanization rates differ significantly; many ASEAN countries are experiencing rapid urbanization, leading to increased energy demand for infrastructure development and urban living (Nathaniel and Khan, 2020). In contrast, well-developed regions have already undergone significant urbanization phases. Additionally, energy policies, resource availability, and climate conditions also play a role. Some ASEAN nations might rely heavily on energy-intensive industries or experience climatic factors necessitating higher electricity use for cooling, while the OECD and EU countries may prioritize energy efficiency and have milder climates (De Cian and Sue Wing, 2019).

The significance of these findings is substantial. Nonstationarity in energy consumption, as observed in many ASEAN countries, points to the need for flexible and robust energy management strategies capable of adapting to long-term changes. The presence of structural breaks indicates that these nations are grappling with various factors such as economic development, population growth, and industrial activities that influence energy consumption patterns over an extended period. In contrast, the stationarity of Brunei suggests a different energy landscape, where short-term interventions may be more effective.

4. CONCLUSIONS AND POLICY IMPLICATIONS

We delved into the crucial aspect of per capita electricity consumption in ASEAN countries, shedding light on its stationarity properties and uncovering vital insights for energy policy-making. The paper addressed a significant research gap by concentrating solely on electricity consumption, a pivotal energy form vital for economic and societal functions, particularly within the context of the ASEAN region. Our investigation, employing the sophisticated Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test with structural breaks, presented nuanced findings. The results revealed a remarkable distinction among ASEAN nations regarding the stationarity of per capita electricity consumption. The majority of countries, including Indonesia, Thailand, Singapore, Vietnam, Malaysia, the Philippines, Myanmar, and Cambodia, exhibited nonstationary electricity consumption patterns. This implies susceptibility to prolonged fluctuations influenced by various structural factors such as economic shifts, population dynamics, and industrial developments. Consequently, these nations face challenges in ensuring stable and sustainable energy systems. The imperative arises for the development of resilient energy management strategies capable of navigating these persistent variations effectively. Interestingly, Brunei stood out as an exception with stationary electricity consumption, suggesting that energy demand shocks in this country have temporary effects. Energy policies in Brunei are anticipated to exert a transient impact on consumption patterns, indicating a different energy landscape than its counterparts.

The significance of these findings cannot be overstated. Nonstationarity in energy consumption points to the need for flexible and robust energy management strategies capable of adapting to long-term changes. The presence of structural breaks underscores the complex interplay of factors influencing energy consumption patterns over extended periods. Policymakers in nonstationary countries must craft adaptive energy policies addressing both immediate needs and the long-term nonstationary nature of energy consumption. Implementing flexible approaches capable of dynamically responding to the evolving energy landscape is paramount.

The findings of this study open avenues for further research in several areas. Firstly, exploring the specific structural factors influencing electricity consumption patterns in nonstationary countries can provide targeted insights for policy formulation. Understanding the interplay of economic, demographic, and industrial factors can enhance the precision of policy interventions. Additionally, investigating the impact of nonstationary energy consumption on related sectors such as healthcare, education, and manufacturing can uncover the ripple effects of prolonged fluctuations. Research in these areas can provide a comprehensive understanding of the broader economic implications of nonstationary energy consumption, guiding policymakers in devising holistic strategies. Furthermore, comparative analyses between stationary and nonstationary countries can offer valuable insights into the effectiveness of different policy approaches. Studying the outcomes of policy interventions in both contexts can provide a rich source of knowledge for policymakers across the ASEAN region and beyond.

The nonstationary nature of per capita electricity consumption in most ASEAN countries necessitates the formulation of adaptive energy policies. Policymakers must focus on developing flexible strategies that can respond effectively to prolonged fluctuations. Such policies should not only address immediate energy demands but also be equipped to handle long-term changes influenced by diverse structural factors. Special attention needs to be given to sectors such as manufacturing, healthcare, and education, which are heavily reliant on electricity. This ensures that their operations remain stable even in the face of persistent fluctuations. Additionally, it is crucial to consider the long-lasting effects of these policies on nonstationary countries. Government policies intended to stabilize electricity demand will have a significant impact in nonstationary countries, and therefore, governments should adopt necessary policy targets for electricity demand levels to ensure stability. In contrast, the stationary electricity consumption in Brunei calls for a different policy approach. Policymakers in Brunei have the opportunity to implement short-term interventions with confidence, as these are likely to have a temporary impact on consumption patterns. However, this stability should not breed complacency. Brunei should continuously monitor global and regional energy trends to anticipate potential shifts in the future, allowing for proactive policy adjustments when necessary.

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