"ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH NEXUS:

SECTORAL ANALYSIS IN THE PHILIPPINES"

A Thesis Presented to the

Graduate School of Public Policy, The University of Tokyo

In partial fulfillment of the requirements for the

Master of Public Policy/International Program

Degree

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June 2020

Acknowledgements

This thesis is dedicated to my recently deceased cousin Amanda Garces, who had always been my younger sister for being my inspiration in completing my degree.

I would like to express my sincerest gratitude and appreciation to my academic supervisor, Professor Jun Arima, for his overwhelming guidance and support throughout the research process. The insights and practical experiences he shared were instrumental in defining the path of my research. I am also grateful to the Japan International Cooperation Agency for choosing me to be part of their SDGs Global Leadership Program and for supporting and funding my studies at the University of Tokyo. I would also like to acknowledge the National Economic and Development Authority of the Philippines for allowing me to pursue higher studies and further my knowledge in the field of public policy to be able to better contribute to the development of my country.

Special thanks to my friends from the Philippine government and the private sector for providing valuable insights and feedback on my research. I would also like to thank the professors and administrative staff of the Graduate School of Public Policy who have helped me throughout my university life. Lastly, my heartfelt gratitude goes to my family and friends who have encouraged me to go after my dreams and have supported me every step of the way.

Abstract

This thesis examined the existence of short-run causality in the four major sectors of the economy, namely: commercial, industrial, residential, and transport and agriculture, forestry, and fishing (TAFF), and long-run causality at the aggregate level between electricity consumption and economic growth in the Philippines for the period 1998-2018. Pedroni's panel cointegration test was used to determine the existence of a long-run equilibrium relationship between the variables, and an Auto Regressive Distributed Lag - Error Correction Model was used to estimate the short- and long-run coefficients as well as to determine the direction of causality between the variables. Empirical results indicated bidirectional causal relationship among all the sectors in the long-run while a short-run causal relationship from economic growth to electricity consumption was found for the commercial and residential sectors, but for the industry and TAFF sectors, no evidence of a causal relationship was found. Policy implications highlighted the importance of pursuing electricity security both in the short and long term as well as the need for the government's commitment to clean energy transition and improved energy efficiency while maintaining affordable electricity rates in expanding economic growth and in moving towards a more sustainable future for all.

Keywords: economic growth; electricity consumption; panel cointegration; ARDL-ECM; Granger causality; Philippines

Table of Contents

List of Figures, Tables, and Appendices

Figures

Tables

Appendices

1. INTRODUCTION

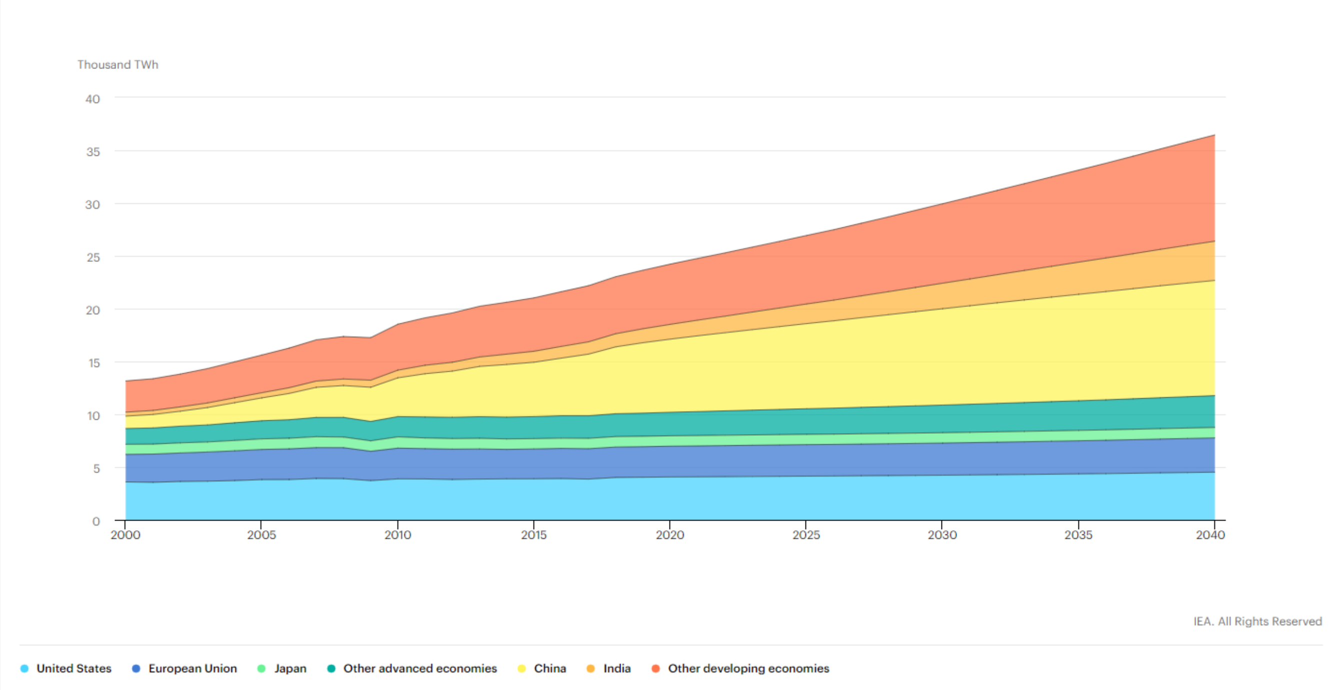
Energy has proven to be a significant contributor to economic growth and development by improving the efficiency and productivity of the country. The widespread industrialization, urbanization, and continued increase in population, particularly in developing countries, has further increased worldwide energy consumption. Dantama et al. (2011) pointed that energy's role is not only limited to the socioeconomic development of the country but is also essential in improving the people's quality of life and standard of living.

Energy can be disaggregated into different resources such as oil, gas, coal, renewables, and electricity. Historically, oil has been the most frequently used proxy indicator for energy in various energy economics studies (Masih and Masih (1996), Asafu-Adjaye (2000), Lau et al. (2011), and Dahmardeh et al. (2012)). However, over the past few decades, electricity has emerged to be a critical and quality energy component by supporting a wide range of products and services as well as fostering technological advancements that stimulate economic growth (Adom, 2011).

According to the International Energy Agency, the electricity sector is now seen as a more attractive investment than both oil and gas, which is a milestone in the energy sector history. Global electricity demand has also doubled between 1960 and 2016 and is expected to increase by more than 50 percent in 2040 in the Stated Policies Scenario[1] (Figure 1).

[1] The Stated Policies Scenario reflects the impact of existing policy frameworks and today's announced policy intentions. The aim is to hold up a mirror to the plans of today's policy makers and illustrate their consequences for energy use, emissions and energy security. Source: International Energy Agency

Figure 1. Global electricity demand by region in the Stated Policies Scenario, 2000-2040

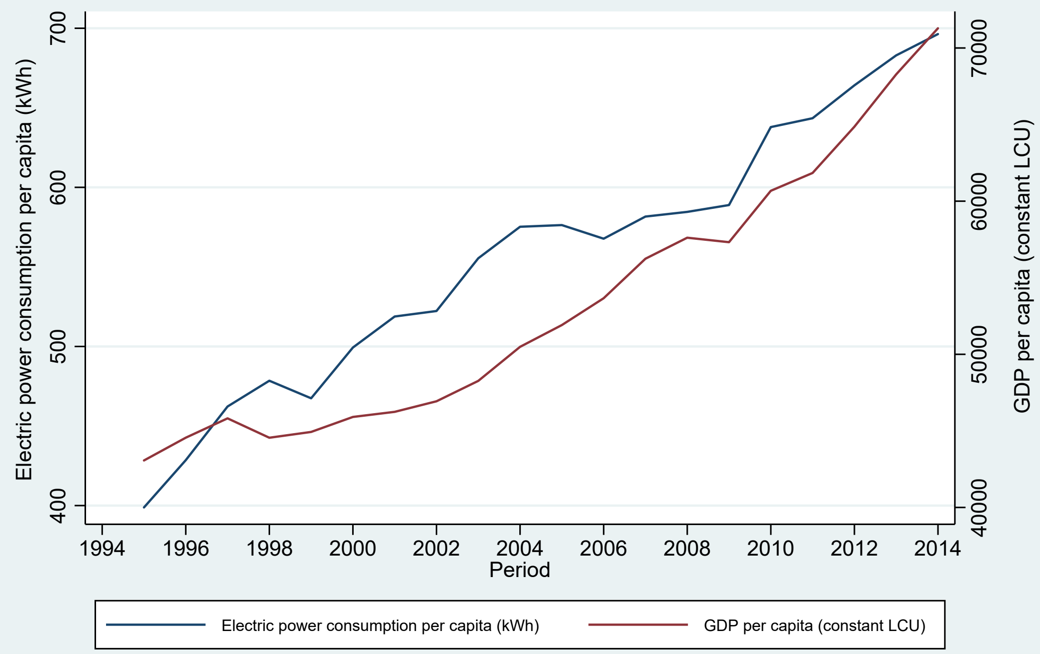


Source: World Energy Outlook 2019, International Energy Agency

In the case of the Philippines, electricity remained to be the universal source of household energy.[2] It is highly demanded and consumed because of its significant use in providing essential services, creating jobs as well as offering comfort and recreation that all together improved the quality of life. Figure 2 shows the high correlation between electricity consumption (EC) and gross domestic product (GDP) in the Philippines from 1995-2014, which makes the country level applicability of the EC and economic growth nexus worth investigating.

[2] https://psa.gov.ph/content/electricity-most-common-source-energy-used-households

Figure 2. Philippines' GDP and power consumption, 1995-2014



Source of raw data: World Development Indicators, The World Bank

The study of Kraft and Kraft (1978) about the causal relationship between energy consumption and Gross National Product (GNP) in the United States[3] opened the academic literature to a whole new field of energy economics and started debates across researchers on the electricity consumption and growth nexus among different countries.

Over the past few decades, many researchers studied the causal relationship between EC and economic growth using different sample periods, countries, and econometric methods. However, no specific relationship was established between the variables. For example, unidirectional causality from EC and GDP was found in China, India, and selected European countries (Shiu and Lam, 2004; Ghosh, 2002; Ciarreta and Zarraga, 2010), while a unidirectional causality from GDP to EC was found in Australia and Western African Countries (Wolde-Rufael, 2006; Narayan and Smyth, 2005). In some cases, bidirectional causality between EC and GDP was evident in selected African

[3] Kraft and Kraft (1978) used gross energy consumption (as a total of all different sources of energy) as one of the variables. The main finding of this study is that causality is unidirectional- running from GNP to energy consumption for the post war period in the United States of America.

countries, Malaysia, Singapore, and Argentina (Shiu and Lam, 2004; Ciarreta and Zarraga, 2010; Ghosh, 2002; Soytas and Sari, 2003). Lastly, some studies resulted in no causal relationship between the variables (Acaravci and Ozturk, 2010; Mozumder and Marathe, 2007). The general findings of the afore-cited studies revealed varying and contradictory results, which raises the need to conduct further empirical testing.

In the case of the Philippines, only the studies of Masih and Masih (1996)[4] and Chen et al. (2007)[5] investigated the causal relationship between EC and GDP, and the said studies showed conflicting results. The discrepancy in literatures and differences in outcomes have motivated the researcher to continue the empirical study using more recent time period, extend the scope on a sectoral level, and address possible policy implications of the results.

Currently, there is no specific empirical study that determined the causality between electricity consumption and GDP using only the Philippines as a case[6]. Furthermore, there is limited literature supporting the electricity-growth nexus by sector (i.e., industrial, commercial, residential, and transport, agriculture, fishery, and forestry) in the country. Thus, it would be worthwhile to study the relationship between the variables at the sectoral level and fill the gap in existing literature.

This study aimed to examine the relationship between electricity consumption and economic growth, using the Philippines as a sample. Furthermore, this study determined the existence of short-run causality per sector and long-run causality at the aggregate level, as well as answered the question as to which variable causes the other- will the increase in

[4] The study found that only the relationships in India, Indonesia and Pakistan were cointegrated. On the other hand, energy consumption and income were non-cointegrated for the case of Malaysia, Singapore and Philippines.

[5] The study confirmed a long-run causality, in Hong Kong and Korea while a short-run causality in Singapore, Philippines, Malaysia and India, from GDP to EC.

[6] There is no existing study (based on the review of the researchers) that used the Philippines as the only sample. Usually, studies on the Philippines are combined with cross-country samples; hence, it did not have a detailed expository discussion on the individual experiences of the countries included in the sample and the implication of results.

electricity consumption lead to an increase in GDP per sector, or will the increase in GDP raise electricity consumption? Policy implications provided the need for a more responsive and sustainable energy policies in the Philippines.

2. REVIEW OF RELATED LITERATURE

The role of electricity in the economy and society has been growing rapidly, and it is causing a major transition to the global energy system. Digitalization has changed the way we live, and countries have become heavily dependent on electricity to function.

Over the last three decades, many studies have been undertaken to analyze energy consumption and economic growth nexus. And as electricity becomes a more critical actor in the global energy system, examining the relationship between these variables has received considerable attention from academic researchers and institutions worldwide.

From the literature, four hypotheses were formulated. First, there is unidirectional causality from electricity consumption and economic growth. Second, a unidirectional causality from economic growth and electricity consumption exists. Third, there is bidirectional causality between the two variables. And fourth, there is no causality between the two variables.

2.1 There is unidirectional causality from electricity consumption and economic growth (GDP)

Numerous studies provided evidence to the causal relationship running from electricity consumption and economic growth. Aqeel and Butt (2001) found unidirectional causality from electricity consumption to GDP in Pakistan using the cointegration test and Hsiao's version of Granger causality for the period 1956 to 1996. Ghosh (2002) showed that electricity consumption Granger caused GDP in India for the period 1950-1997 using the Engle-Granger approach and standard Granger causality test. Using the Cointegration Test, Maximum Likelihood Procedure, and Granger Causality test, Soytas and Sari (2003) found evidence that electricity consumption Granger caused GDP in Turkey, France, Germany and Japan for the period 1950-1992. Using the Cointegration Johansen Approach in the data set for China with the period 1971-2000, Shiu and Lam (2004) proved a unidirectional causality running from electricity consumption and GDP in China using data set from 1971-2000. In the case of Shanghai, Wolde-Rufael (2004), found the same causal relationship for the period 1952-1999. For Turkey in the period 1950-2000, Altinay and Karagol (2005) confirmed the existence of unidirectional causality running from electricity consumption and GDP using the Unit Granger causality test. Wolde-Rufael (2006) proved that there is a positive unidirectional causality from electricity consumption per capita to GDP per Capita in two countries in Africa (Benin and the Democratic Republic of the Congo), while a negative unidirectional causality was found in the case of Tunisia for periods 1971 to 2001 using Pesaran et al. (2001) Cointegration Test and Granger causality test. Lee and Chang (2007), who studied the co-movement and causal relationship of sixteen Asian countries during 1971-2002, found substantial evidence of bidirectional causality among developed countries and unidirectional causality from GDP per capita to energy consumption per capita in developing countries.

Ho and Siu (2007) showed evidence of unidirectional causality from electricity consumption and GDP in Hong Kong using Cointegration, VECM model, and Granger causality for annual data periods from 1966 to 2002. For OPEC members such as Indonesia, Nigeria, and Venezuela, a positive unidirectional causality was found from electricity consumption to GDP in the study of Squalli (2007), using Bound Tests. Using several methods such as stationarity, ECM, and cointegration theory, Yuan et al. (2007) showed that only a short-run unidirectional causality from electricity consumption to GDP exists in China, which means that electricity shortages can hamper China's economic growth. Chen et al. (2007) found a long-run causality in Indonesia and a short-run causality from electricity consumption to GDP for Hong Kong in his study on the relationship between GDP and electricity consumption in ten Asian countries showed evidence for unidirectional causality from electricity consumption to GDP in Australia, Iceland, Italy, the Slovak Republic, the Czech Republic, Korea, Portugal, and the UK, using the Bootstrapped Causality Test for thirty OECD countries.

Akinlo (2009) proved that electricity consumption Granger caused economic growth for Nigeria in the period 1980-2009. Ciarreta and Zarraga (2010) identified the Granger causal relationship in the panel data of 12 European Countries (Austria, Belgium, Denmark, Finland, France, Germany, Italy, Luxembourg, Netherlands, Sweden, Norway, and Switzerland) for periods 1970 to 2007, and found a short run and strong negative unidirectional causality running from electricity consumption to real GDP using unit root test, Cointegration and a Dynamic Panel Estimation approach. Yoo and Kwak (2010) proved a unidirectional causality ran from electricity consumption to economic growth in Argentina, Brazil, Chile, Columbia, and Ecuador covering the period 1975 to 2006. According to Kouakou (2011), a unidirectional causality running from electricity consumption to GDP in the long-run exists in Cote d' Ivoire. In the study by Apergis and Payne (2011) about the relationship between electricity consumption and economic growth of eighty-eight countries, which is further grouped into World Bank's classification of income that consists of four panels namely high, upper-middle, lower-middle and low income over the periods 1990 to 2006, found that in the short-run, there was unidirectional causality running from electricity consumption to economic growth in the lower-middle-income country panel and low-income country panel using panel error correction models and panel vector autoregressive model respectively. This means that energy conservation policies will have a negative effect on these countries' economic growth.

In general, unidirectional causality from energy (electricity) consumption and economic growth was observed in countries with energy (electricity) intensive industry sector and that the industry sector's share to total GDP is large enough to have a contributory effect to GDP. Since industrial production contributes a large share of total GDP, the growth in the demand for electricity in the industry sector increases industrial output, which in turn, increases GDP. Investments in power infrastructure and supply capacity are crucial in avoiding any shocks or shortages in electricity supply that will adversely affect economic growth.

2.2 There is unidirectional causality from economic growth (GDP) and electricity consumption

Many studies, using different countries as a sample with varying periods, provided support to the claim that GDP causes electricity consumption. Ghosh (2002) a unidirectional Granger causality coming from GDP per capita to electricity consumption per capita in India for annual data covering periods 1950-51 to 1996-97. Soytas and Sari (2003) provided evidence of causality from GDP to electricity consumption in Korea and Italy using the Granger causality test. Narayan and Smyth (2005) proved that GDP caused electricity consumption in Australia using the data set from 1966-1999 and applying the cointegration and Granger causality test. Using the Engel-Granger cointegration test and Hsiao's version of Granger causality, Yoo (2006) concluded that GDP Granger caused electricity consumption in Thailand and Indonesia using the period 1971-2002. Wolde-Rufael (2006) found a unidirectional causality from GDP per capita to electricity consumption per capita in six countries in Africa (Cameroon, Ghana, Nigeria, Senegal, Zambia, and Zimbabwe) for periods 1971 to 2001 using Pesaran et al. (2001) cointegration test and Granger causality test. Squalli (2007) provided evidence supporting the unidirectional causality from GDP to electricity consumption hypothesis in countries such as Kuwait, UAE, and Saudi Arabia while OPEC members such as Algeria, Iraq, and Libya had found to have negative causality. Chen et al. (2007) found a long-run causality in Hong Kong and Korea while a short-run causality in Singapore, Philippines, Malaysia, and India, from GDP to electricity consumption was found in his study on ten Asian countries. Narayan and Prasad (2008) found a unidirectional causality from GDP to electricity consumption in the UK, Korea, Finland, Hungary, Iceland, and the Netherlands, using the bootstrapped causality test for thirty OECD countries. Akinlo (2008), using the VAR framework showed unidirectional causality running from economic growth to energy consumption for Congo. In the research by Pao (2009) using cointegration and error-correction models for data during 1980-2007, it was evident that a unidirectional Granger causality from economic growth to electricity consumption exists in Taiwan. For Africa and G6 countries, Narayan et al., (2010) found a negative causality from GDP to electricity consumption, which means that as these countries increase their consumption for electricity, GDP will be gradually reduced. In Pakistan, a unidirectional causal relationship running from GDP to electricity consumption was observed at the aggregate level for periods 1960 to 2008. This indicates that higher GDP motivates greater electricity demand (Jamil and Ahmad, 2010). Bildirici et al. (2012), in his study of the eleven Commonwealth Independent States that were further subcategorized into three groups, found a positive unidirectional causality from GDP to electricity consumption in the short-run for the first group of countries. The first group consisted of countries (Russian Federation, Azerbaijan, Republic of Belarus, and Kazakhstan) that had GDP per capita that ranges from $1900 to $2500.

A unidirectional causality from economic growth to electricity consumption was observed in economies where economic growth caused expansion in the commercial and industrial sectors in which electricity has been used as a basic energy input. This implies that further growth in industrial output and commercial services will lead to a higher demand for electricity consumption. Besides, higher economic growth has also caused disposable income to increase, allowing households to be more dependent on electricity both for recreation and comfort; thus, further increasing electricity demand.

2.3 There is bidirectional causality between electricity consumption and economic growth (GDP)

Several published research provided evidence to the bidirectional causal relationship between electricity consumption and economic growth. Soytas and Sari (2003) found bidirectional causality between electricity consumption and GDP in Argentina. Guttormsen (2004) observed bidirectional causality between electricity consumption and GDP in the countries France, Germany, Greece, Italy, Japan, Argentina, and India using data set from 1960-2002. Jumbe (2004) proved that electricity consumption and economic growth have bidirectional causality in Malawi using Cointegration and Error Correction Vector Techniques. For the case of Korea, Lee (2004) found a long-run bidirectional causal relationship between energy consumption and GDP. Malaysia and Singapore for the period 1971-2002 also provided evidence to the hypothesis of bidirectional causality between GDP and electricity consumption (Yoo, 2006). Wolde-Rufael (2006) found bidirectional causality from electricity consumption per capita to GDP per Capita in three countries in Africa (Egypt, Gabon, and Morocco) for periods 1971 to 2001 using Pesaran et al. (2001) cointegration test and Granger causality test. Squalli (2007), using bound test, provided evidence of bidirectional causality between electricity consumption and economic growth for Iran and Qatar. Odhiambo (2009), observed bidirectional relationship between electricity consumption and GDP in South Africa using a dynamic Granger causality approach, error-correction mechanism, and incorporating employment rate as an intermittent variable. A bidirectional causal relationship between electricity consumption and real GDP both in the short and long run was evident in Burkina Faso using Cointegration analysis (Oedraogo, 2010). The study of Yoo and Kwak (2010) showed bidirectional causality between electricity consumption and economic growth in Venezuela covering the period 1975 to 2006. Kouakou (2011) demonstrated a short-run a bidirectional causality between electricity consumption and GDP for Cote d' Ivoire in the period 1971-2008.

Apergis and Payne (2011) found that there was bidirectional causality from electricity consumption to economic growth in the high, upper-middle-income country panel both in the short- and long- run and in the lower-middle-income country panel in the long-run only using panel error correction models with data set covering from1990 to 2006. Shahbaz et al. (2011) found a strong bidirectional Granger causality between electricity consumption and economic growth in Portugal in the long-run. Bildirici et al. (2012) in his study on the eleven Commonwealth Independent States (CIS) countries, which are further subcategorized into three groups,[7] found a bidirectional relationship between electricity consumption and GDP in the long-run for all groups and also in the short-run for the third group only using unit root tests, ARDL method, Pedroni Cointegration analysis, fully modified ordinary least squares (FMOLS), and Granger causality test. Wen-Cheng Lu (2016) studied the existence and nature of Granger causality between electricity consumption and economic growth for 17 industries in Taiwan and found a long-run equilibrium relationship and bidirectional relationship between the two variables using panel cointegration and panel Granger causality tests. Hanif et al. (2017) conducted a panel estimation approach and found a bidirectional relationship between

[7] The first group consisted of countries (Russian Federation, Azerbaijan, Republic of Belarus and Kazakhstan) that has GDP per capita that ranges from $1900 to $2500, the second group with GDP per capita from $300 to $800 (Moldova, Tajikistan, Uzbekistan, and Kyrgyzstan) and lastly, the third group which consisted of countries (Armenia, Georgia, and Ukraine) with $1000 to $1500 per capita GDP

electricity consumption and economic growth in ASEAN using data from the year 1983 to 2012.

Bidirectional causality between economic growth and electricity consumption was observed in countries with relatively high electrification levels as well as those that have undergone massive infrastructural developments and structural changes over the years, which have required substantial electricity usage.

2.4 There is no causality between electricity consumption and GDP

Soytas and Sari (2003) found no causality between electricity consumption and GDP in of Indonesia, Poland, and the UK using Cointegration test, Maximum Likelihood Procedure, and Granger causality test. Chen et al. (2007) found no evidence of long-run causality between GDP and electricity consumption in India, Singapore, Taiwan, and Thailand and no short-run causality in Indonesia, Korea, Taiwan, and Thailand. Long-term causality between electricity consumption per capita and real GDP per capita was not observed in fifteen transition countries (Albania, Belarus, Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russian Federation, Serbia, Slovak Republic, and Ukraine) using data sets from 1990 to 2006 (Acaravci and Ozturk, 2010). Peru showed no granger causality for the period 1975 to 2006 (Yoo and Kwak, 2010). Apergis and Payne (2011) confirmed that there is no long-run equilibrium relationship between electricity consumption and economic growth in low-income country using panel estimation. Gurgul and Lach (2012) using quarterly data of GDP, total electricity consumption, and industrial electricity consumption, found no causal relationship among the variables for the case of Poland. Tang and Shahbaz (2013), exhibited the same findings for the case of Pakistan using agricultural electricity consumption and GDP. The research tested different sectors, namely, manufacturing, service, and agricultural, and found mixed results. Lastly, Akkemik and Gokal (2012) tested panel data for 79 countries, and two-tenth of them showed no causality between electricity consumption and GDP.

The lack of a significant relationship between economic growth and electricity consumption in some countries is partly because electricity has not been used extensively in the production of goods and services and that electricity is not the main source of energy supply, such as the bulk of African countries. Moreover, in many developing Asian countries, the occurrence of wasteful use of electricity or high electricity usage inefficiency in the different sectors of the economy has been observed. Lastly, the absence of causality may also be attributed to some omitted variables that may be important in determining economic growth and stimulating electricity demand.

Synthesis

The researcher found several studies on the electricity consumption and growth nexus, but contradicting results were observed from different journals. Some empirical research concluded that there is bidirectional causality between electricity consumption and economic growth, while others found unidirectional causality. To some extent, some literature concluded no causal relationship between the two variables.

Mixed results can be explained by the different sample countries, periods, econometric model, and short-run, and long-run span of analysis. For instance, in the case of the Philippines, where only the studies of Masih and Masih (1996) and Chen et al. (2007) have been conducted, conflicting results were observed. Masih and Masih (1996) found no causality between economic growth and energy consumption, while Chen et al. (2007) found a unidirectional causality from economic growth to electricity consumption. The variation in results can be attributed to the different time periods used in the study. Masih and Masih (1996) used 1955-1991 as a sample period. During this period, the Philippines has experienced economic and political unrest brought by a debt-driven growth and the imposition of the Martial law during half of the sample period. On the other hand, Chen et al. (2007) use 1971-2001 as sample period, where economic reforms were accompanied by several reforms in the power sector such as the amendment of the Build-Operate-Transfer Act, enactment of Emergency Power Crisis Act, and increased negotiated Independent Power Producer contracts which resulted to investments of 4800MW of installed capacity, among others (The World Bank, 2019). The moderate economic growth of the country during the sample period, coupled with the reforms in the power sector, contributed to higher electricity consumption resulting in a unidirectional causality from economic growth to electricity consumption.

The study will be significant because it focuses on the Philippines, which only the studies of Chen et al. (2007) and Masih and Masih (1996) have been conducted. It will also fill in the existing gap in literature by analysing the causal relationship between electricity consumption and GDP on a sectoral level. In addition to that, the study will also be critical in signifying policy directions concerning electricity consumption and economic growth.

Blanchard (2010) stressed the relationship between production and demand wherein production itself depends on demand. This best explains the classical macroeconomic theory of economic growth, which states that consumption is part of the aggregate demand equation; hence an increase in consumption will trigger an increase in output and income. The researcher examined if this is true for electricity consumption and GDP by sector in the short-run and at the aggregate level in the long-run for the case of the Philippines.

3. RESEARCH METHOD

To determine the relationship between electricity consumption (EC) and economic growth (GDP) in the case of the Philippines, the researcher used secondary data from 1998 to 2018 obtained from the Department of Energy for electricity consumption; and from the Philippine Statistics Authority for economic growth[8]. The variables are then expressed in the natural logarithmic form to reduce the issues of heteroskedasticity.

Many previous empirical types of research on the subject used aggregated data both in developed and developing countries; however, Soytas and Sari (2007) pointed out that many issues might suffer from aggregation bias. Thus, this study used sector-specific data to determine the short-run causal relationship between electricity consumption and economic growth in four sectors, namely residential, commercial, industrial, and transport and agriculture, forestry, and fishing (TAFF). Sector-specific analysis can help address the heterogeneous effects of energy (electricity) conservation policies on various sectors which have different energy usage intensities.

The study used panel estimation econometric analysis to give light to the relationship between the EC and GDP in the Philippines. First, the unit root test was carried out by using both Levin et al. (2002) and Im et al. (2003) or LLC and IPS unit root tests, respectively. The test results determined the stationary properties and order of integration of the variables. Second, the long-run cointegration relationship between the variables was tested using Pedroni's Cointegration Test (1995). Third, conditional on finding Cointegration, ARDL approach was used for the Cointegration analysis. Lastly, the Error Correction Model (ECM) was employed to explore both the short-run and long-run causal relationships between the variables.

3.1 Panel unit root tests

A unit root test was performed to determine the stationarity and order of integration

[8] Gross Value Added was used to reflect economic growth/GDP in industry, services, and transport and AFF sectors x Household Final Consumption Expenditure on electricity, water, gas, and other fuel was used to reflect economic growth/GDP in the residential sector.

of the variables[9]. The traditional univariate unit root test developed by Dickey and Fuller (1979, 1981) has low power[10] problems, which makes it difficult to reject the null hypothesis when it is not true. Because of the weakness of the traditional unit root test, the LLC and IPS panel unit root tests, which have been extensively used in panel data estimations, were used in this study.

The LLC panel unit root test is based on the following model:

$$y_{it} = \rho_i y_{i,t-1} + z'_{it}\gamma + u_{it} \quad i = 1, \dots, N\,; t = 1, \dots, T \tag{1}$$

where z_{it} is the deterministic component and u_{it} is the stationary process. The LLC test allows for heterogeneity in the intercept terms and assumes that the residuals are independently and identically distributed with mean zero and variance σ_u^2 and $\rho_i = \rho$ for all values of i. The null hypothesis is that all series in the panel have unit root ($H_0 : \rho_i = \rho = 0$ for all i) whereas the alternative hypothesis is that all series are stationary ($H_a : \rho_1 = \rho_2 = \cdots = \rho < 0$ for all i).

On the other hand, the IPS test is less restrictive than the LLC test as it allows for heterogeneity both in intercept and slope terms for the cross-section units. The basic equation for the IPS test can be specified as:

$$y_{it} = \rho_i y_{i,t-1} + \sum_{j=1}^{p_i} \varphi_{ij} \Delta y_{i,t-j} + z'_{it}\gamma + u_{it} \quad i = 1, \dots, N\,; t = 1, \dots, T \tag{2}$$

The null hypothesis states that all series in the panel have unit root ($H_0 : \rho_i = \rho = 0$ for all i) versus the alternative hypothesis is that at least one series in the panel is stationary (H_a: $\rho_i < 0$ for some $i = 1, 2, \dots, N_1$ and $\rho_i = 0$ for $i = N_1 + 1, \dots, N$). The IPS statistic is based on averaging individual ADF statistics and shows that under the null

[9] A time series has stationarity if a shift in time doesn't cause a change in the shape of the distribution; unit roots are one cause for non-stationarity. Analyzing time series with the existence of unit roots can cause spurious regression, that there is a high chance of getting high r-squared values even if the data is uncorrelated.

[10] The power of a test is the probability of rejecting the null when it is false and the null hypothesis is unit root.

hypothesis of non-stationary, the t-statistic follows the standard normal distribution asymptotically.

3.2 Panel cointegration test

Pedroni's (1995) panel cointegration test was used to test for the existence of a long-run relationship between EC and GDP by sector in the Philippines. Variables are said to be cointegrated if their linear combination has a lower order of integration. Cointegration implies the existence of a long-run relationship between the variables.

Pedroni considers the heterogeneity across the cross-sections by allowing individual-specific fixed effects, slopes, and deterministic time trend for each cross-section. The panel cointegration test equation is specified as:

$$Y_{jt} = \alpha_j + \delta_{jt} + \beta_j X_{jt} + e_{jt} \tag{3}$$

The null hypothesis states that there is no cointegration between the variables in all panels, while the alternative hypothesis is that cointegration between the variables in all panels exists.

3.3 ARDL Approach

The ARDL approach suggested by Pesaran et al. (1997, 2004) has been widely used to analyze cointegration in single-equation models. This method has been used by Bildirici and Kayikci (2012) to study the energy-growth nexus in Commonwealth Independent States countries and by Binder and Offermanns (2007) for analyzing the purchasing power parity in Europe.

The ARDL approach usually consists of two steps. The first is to determine if a long-run relationship exists between the variables. Upon confirming the cointegration (there is a long-run relationship) between the variables, the second step is to estimate the long-run coefficients using the ARDL model. According to Pesaran et al. (1997, 2004), cross-equation restrictions to the long-run parameters must be implemented by maximum likelihood estimation, and to validate the said restrictions, the Hausman (1978) test was used. From the Hausman test, the pooled mean group (PMG) was used for the estimations. PMG estimator allows for the short-term coefficients and error variances to differ across groups but limits the long-run coefficients to be identical. In this study, the ARDL model to be estimated using the PMG estimator is as follows:

$$\Delta GDP_{i,t} = \omega_i + \sum_{j=1}^{m-1} \alpha_{ij} \Delta GDP_{i,t-j} + \sum_{l=0}^{n-1} \beta_{il} \Delta EC_{i,t-l} + \delta_1 GDP_{i,t-1} + \delta_2 EC_{i,t-1} + \varepsilon_{1,it} \quad (4)$$

$$\Delta EC_{i,t} = \omega_i + \sum_{j=1}^{m-1} \alpha_{ij} \Delta EC_{i,t-j} + \sum_{l=0}^{n-1} \beta_{il} \Delta GDP_{i,t-l} + \varphi_1 GDP_{i,t-1} + \varphi_2 EC_{i,t-1} + \varepsilon_{2,it} \quad (5)$$

where GDP and EC are the natural logarithmic form of gross domestic product and electricity consumption and Δ represents the first difference operator. $i = 1, \dots, N$ are cross-section units, $t = 1, \dots, T$ are the time periods, and ω_i denotes the sector-specific intercept.

3.4 Granger Causality

Lastly, the researcher conducted the Granger causality test proposed by Clive W.J. Granger in 1969, who defined causality using the foresee ability as a yardstick, which is called Granger causality. He stated that past can cause present or future events, but future events cannot since time does not run backward.

Further, according to Granger causality, X "Granger causes" Y if past values of X contain information that helps predict the value of Y, rather than using the past values of Y alone. Relating the concept of Granger causality using EC and GDP, Granger causality implies that EC is said to Granger cause GDP if GDP can be better predicted by past values of both EC and GDP than with only the past values of GDP.

To determine the short-run and long-run causality between the variables, an ECM according to the Granger representation theorem was constructed as follows:

$$\Delta GDP_{i,t} = \omega_i + \sum_{j=1}^{m-1} \alpha_{ij}\, \Delta GDP_{i,t-j} + \sum_{l=0}^{n-1} \beta_{il}\, \Delta EC_{i,t-l} + \tau_1 ECT_{1,it-1} + \varepsilon_{1,it} \quad (6)$$

$$\Delta EC_{i,t} = \omega_i + \sum_{j=1}^{m-1} \alpha_{ij}\, \Delta EC_{i,t-j} + \sum_{l=0}^{n-1} \beta_{il}\, \Delta GDP_{i,t-l} + \tau_2 ECT_{2,it-1} + \varepsilon_{2,it} \quad (7)$$

where $ECT_{1,it-1}$ and $ECT_{2,it-1}$ are the error correction terms resulting from the long-run equilibrium relationship, and τ_1 and τ_2 indicate the speed of adjustment to the equilibrium level after a shock.

The PMG estimator was used to estimate the ECM model in Equations (6) and (7) and evaluate the Granger causality relationships. To determine the short-run causality, the significance of the coefficients related to the lagged difference of EC in Equation (6), and GDP in Equation (7) is evaluated ($H_0 : \beta_{il} = 0;$ for all i and $l \geq 1$). The long-run causality, on the other hand, is evaluated through the coefficient of ECT ($H_0 : \tau_1$ and $\tau_2 = 0$).

4. EMPIRICAL RESULTS, INTERPRETATION, AND ANALYSIS

4.1 Data

The electricity consumption data by sector (i.e., commercial, industrial, residential, and transport and agriculture, forestry and fishing (TAFF)[11]) was taken from the Department of Energy for the period 1998 to 2018 while the data on economic growth for the same period was taken from the Philippine Statistics Authority. Measured at 2000 constant prices, the gross value added was used to reflect economic growth (GDP) in industry, services, and TAFF sectors while household final consumption expenditure on electricity, water, gas, and other fuel was used to reflect economic growth (GDP) in the residential sector. Table 1 shows the descriptive analysis of the data. The variables are then expressed in the natural logarithmic form.

[11] Data consists of electricity consumption of all other sectors not classified under the commercial, industrial and residential sectors.

Table 1. Descriptive Statistics

Variables	Economic Growth (GDP_i)				Electricity Consumption (EC_i)			
Sectors	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum
Commercial	14.73	0.36	14.23	15.35	9.56	0.32	9.07	10.09
Industrial	14.38	0.32	13.96	14.96	9.77	0.23	9.43	10.23
Residential	12.97	0.26	12.60	13.47	9.77	0.25	9.38	10.25
TAFF	13.83	0.24	13.36	14.16	7.3	0.36	6.83	7.92

Note: All variables are expressed in the form of natural logarithms

	Obs.	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Economic Growth (GDP_i)	84	13.98	0.73	12.60	15.35
Electricity Consumption (EC_i)	84	9.11	1.08	6.83	10.25

Note: All variables are expressed in the form of natural logarithms

4.2 Panel unit root tests results

To test the stationarity of the data, the researcher used both the Levin, Lin, and Chu (2002) or the LLC and the Im, Pesaran, and Shin (2003) or the IPS panel unit root tests. The variables are said to be stationary if there are no unit roots among the panels. The results of the panel unit root tests are presented in Table 2.

In level, the null hypothesis on the existence of unit roots in the panel data for GDP and EC cannot be rejected. Hence, the variables are non-stationary. However, when the series are in first difference, results showed that the null hypothesis of a unit root is rejected, making the variables stationary. In summary, the results strongly suggest that both EC and GDP are non-stationary in level but stationary in the first difference. This means that the variables are integrated on order one, and since both variables in consideration are integrated of the same order, the presence of the cointegration relationship can be examined.

Table 2. Panel unit root tests results

All Sectors	LLC (trend)	IPS (trend)
GDP	-0.986	2.228
EC	0.111	0.864
ΔGDP	-2.510***	-2.225**
ΔEC	-4.316***	-4.910***

Note:
*** and ** rejects the null hypothesis of unit roots in the series at the 1% and 5% level of significance, respectively.
Δ indicates the variables in the first difference.

4.3 Panel cointegration test result

After confirming that both the series are non-stationary at the level and are integrated of the same order, the cointegration relationship between GDP and EC was examined using the Pedroni (2004) panel cointegration test. Table 3 presents the results of the cointegration test.

It can be concluded that there is cointegration for all four sectors with the null hypothesis of no cointegration being rejected at 1% and 5% level of significance. This empirical result proves that there is a long-run relationship between GDP and EC for all the sectors under study.

Table 3. Panel cointegration test results

All Sectors	Augmented Dickey-Fuller	Philips-Perron
GDP to EC	-2.947***	-2.184**
EC to GDP	-3.233***	-2.210**

Note: *** and ** rejects the null hypothesis of no cointegration in the series at the 1% and 5% level of significance, respectively.

4.4 ARDL PMG estimates and causality results

Equations (4), (5), (6) and (7) were then estimated using the PMG estimator based on the outcome of the Hausman test which showed that the PMG is a more efficient estimator as compared to the dynamic fixed effect estimator (see Appendix for the Hausman test result) and the optimal lag order was selected based on the AIC (Akaike information criterion). Tables 4.1 and 4.2 show the short-run PMG estimates, while Table 5 shows the long-run PMG estimates of the ARDL-ECM model. Long-run and short-run causality were then inferred based on the PMG estimates in Table 4.1, 4.2. and 5. The direction of causality is summarized in Table 6.

Table 4.1 Short-run estimates with ΔGDP as the dependent variable

Sectors	Economic Growth (ΔGDP)
Commercial	0.076
	(0.105)
Industrial	-0.120
	(0.190)
Residential	-0.005
	(0.109)
TAFF	0.047
	(0.041)

Standard errors are in parenthesis

Table 4.2 Short-run estimates with ΔEC as the dependent variable

Sectors	Electricity Consumption (ΔEC)
Commercial	0.821**
	(0.343)
Industrial	-0.079
	(0.245)
Residential	0.711*
	(0.390)
TAFF	0.037
	(1.309)

Standard errors are in parenthesis

** p<0.05, * p<0.1

4.4.1 Short-run[12] PMG estimates and causal directions

The result of the estimates for the commercial and residential sector supports the conservation hypothesis, which indicates a unidirectional causality from economic growth to electricity consumption. This means that economic growth has a positive and significant impact on electricity consumption, while electricity consumption does not have a significant impact on economic growth. A 1% increase in GDP will lead to an increase in electricity consumption in the commercial and residential sectors by 0.82% and 0.71%, respectively. Estimates for the industrial and TAFF sectors, on the other hand, provide evidence to the neutrality hypothesis, which means that there is no causal relationship between economic growth and electricity consumption.

4.4.2 Long-run[13] PMG estimates and causal directions

In the long-run, however, estimates support the feedback hypothesis or the bi-direction causal relationship between the variables for all sectors, which means that economic growth significantly affects electricity consumption and vice versa. In the long run, a 1% increase in GDP will increase electricity consumption by 0.75% while a 1% increase in electricity consumption will increase GDP by 1.48%. This implies that increasing electricity consumption will be an essential engine of economic growth.

[12] Short-run estimates per sector analysis and the existence of a short-run causality depends on the significance of the coefficients related to the lagged difference of EC and GDP in the model. There is no one set rule in determining the exact short run and long run period. In development planning, short-run is usually defined as 5 years or less while long-run refers to period more than 10 years.

[13] Long run estimates the panel data which means estimating all sectors as a whole. The existence of a long-run causality depends on the significance of the coefficient of the error correction terms of the model. There is no one set rule in determining the exact short run and long run period. In development planning, short-run is usually defined as 5 years or less while long-run refers to period more than 10 years.

Table 5. Long-run estimates

		Dependent Variable	
		ΔGDP	ΔEC
Independent Variables	ΔGDP	---	.748*** (0.028)
	ΔEC	1.475*** (0.080)	-

Note: Values in parenthesis are the standard errors. *** indicates statistical significance at 1% level.

Table 6. Summary of causal relationships

Sectors	Short-run causality direction
Commercial	$\Delta GDP \rightarrow \Delta EC$
Industrial	$\Delta GDP \neq \Delta EC$
Residential	$\Delta GDP \rightarrow \Delta EC$
TAFF	$\Delta GDP \neq \Delta EC$
	Long-run causality direction
All sectors	$\Delta GDP \leftrightarrow \Delta EC$

Note: $\leftrightarrow$, $\rightarrow$, and $\neq$ represents bidirectional, unidirectional, and no causality, respectively.

4.5 Analysis of results

John Meynard Keynes "General Theory" (1936) explained that aggregate consumption is directly related to aggregate income; hence an increase in consumption will cause an increase in output and income. This study examined if this macroeconomic theory is true for electricity consumption and GDP for the case of the Philippines.

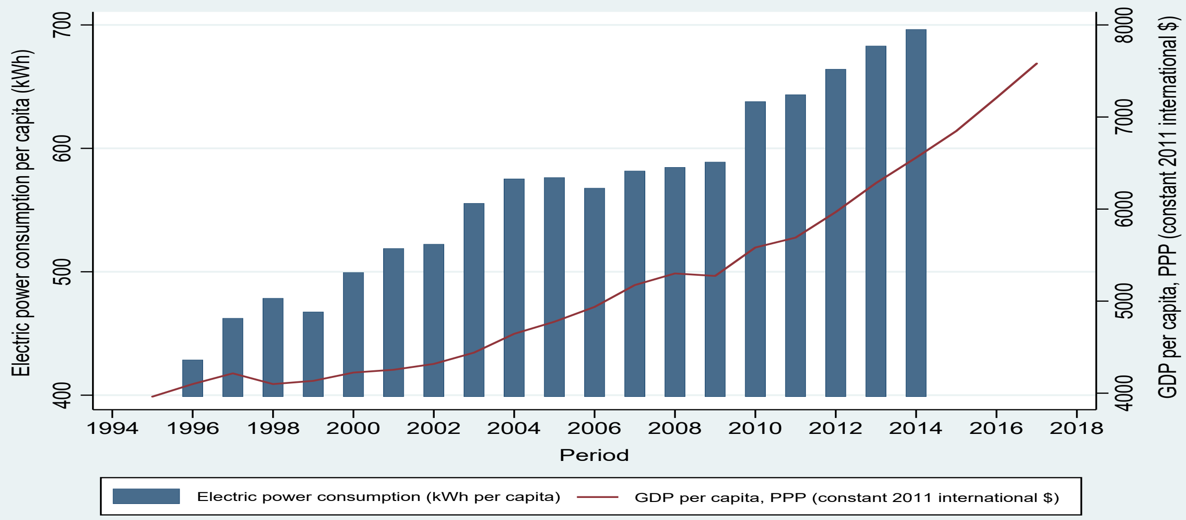
Over the years, the Philippines has implemented various reforms in the power sector, particularly the Electric Power Industry Reform Act of 2001, which paved the way for the establishment of major electricity infrastructures, competitive power market, and nationwide electrification programs. These reforms have complemented the economic growth taking place in the country and have increased not only the electricity supply but also households' access to electricity. In terms of economic growth, the Philippines experienced robust economic growth over the past two decades and have undergone economic structural changes. GDP per capita (PPP at constant 2011 international $) increased by 84.9 percent in 2017 from $ 3,962.60 in 1998.[14] Employment, on the other hand, has also significantly increased by 43.9 percent in July 2018 from around 28 million persons employed in July 1998.[15]

The findings of this study that a unidirectional causality exists from GDP to electricity consumption for both the commercial and residential sectors in the short-run provide evidence to the claim of Chen et al. (2007) that high disposable income leads to higher dependence on electronic gadgets and appliances for a more convenient household. Increases in electric power consumption per capita as GDP per capita increases was evident in the Philippines, as shown in Figure 3.

Electric power consumption per capita increased by 45.5 percent in 2014 from the 474.48 kWh per capita consumption in 1998.[16] Furthermore, the percentage of Filipinos with access to electricity has continuously been increasing owing to the government's effort to achieving universal electricity access as a commitment to the Sustainable Development Agenda 2030. And with the increased access to electricity, access to clean fuels and technologies for cooking has also improved (Figure 4).

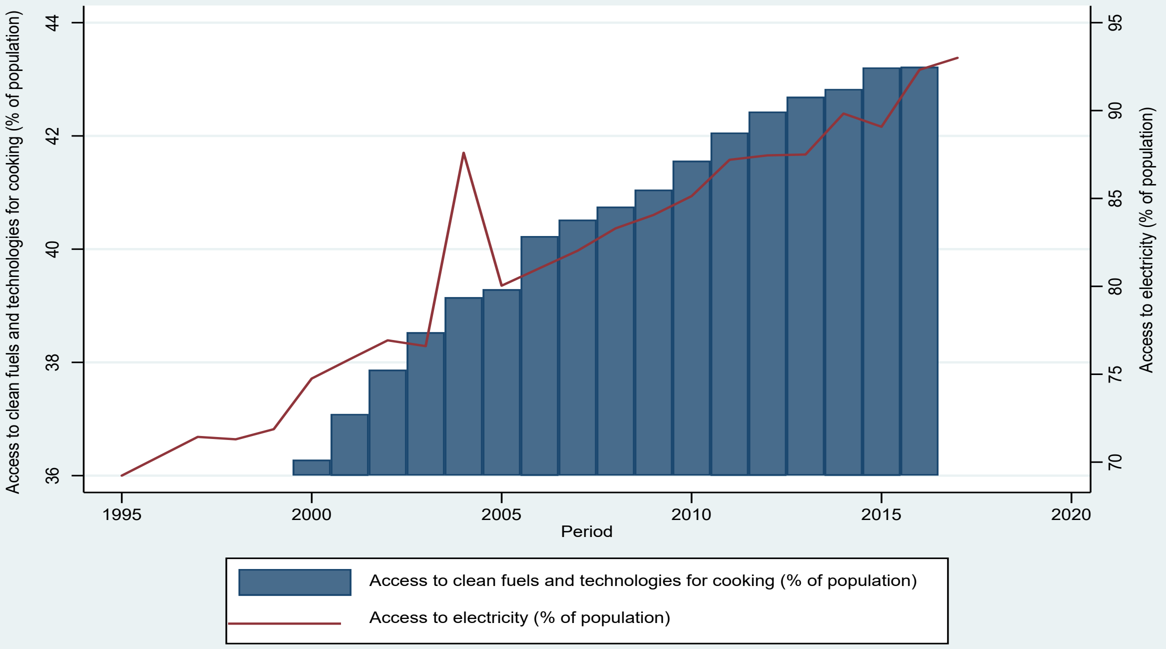
[14] The World Bank: World Development Indicators
[15] Philippine Statistics Authority: Current Labor Statistics and 1998 Labor Force Survey
[16] The World Bank: World Development Indicators

Figure 3. Philippines' GDP per capita and power consumption per capita



Source of raw data: World Development Indicators, The World Bank

Figure 4. Philippines' access to electricity and clean fuels and technologies for cooking

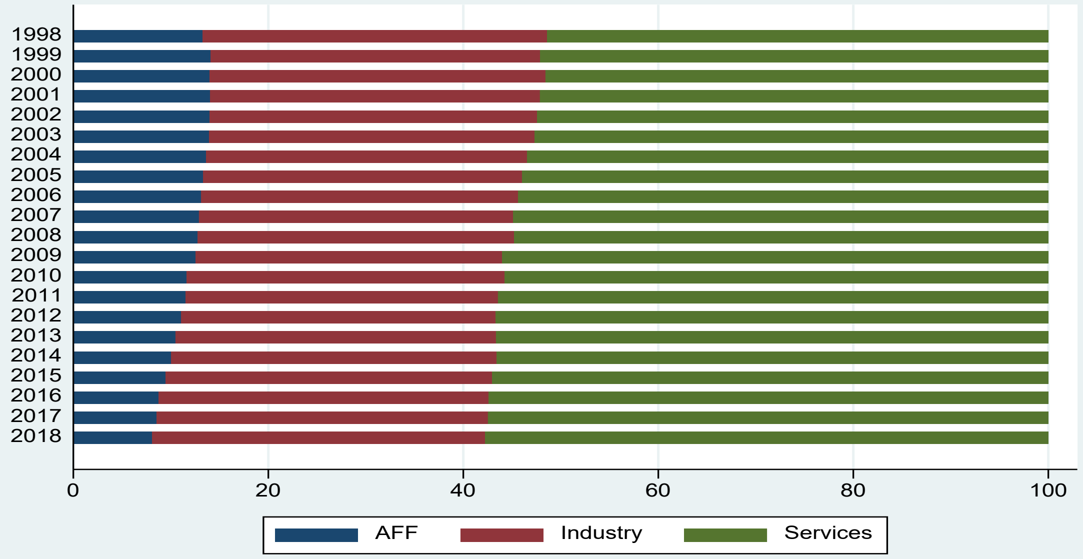


Source of raw data: World Development Indicators, The World Bank

Furthermore, the unidirectional causality from GDP to electricity consumption in the commercial sector may be attributed to the increased investments on the services sector (i.e., business process outsourcing (BPO) industry, accommodation, food service activities, and real estate activities) that may have consequently, increased electricity consumption for powering ICT devices, lighting, and air-conditioning, among others.

The Philippine economy has been driven by a services-led growth, with the services sector growing at an annual average of 5.9 percent for the past two decades (Figure 5). It also accounts for almost 50% of the total output and employs more than half of the total workforce. [17] The investment climate has also improved since the early 2000s with improved competitiveness (from ranking 71st out of 125 countries in 2006 to rank 64th out of 141 countries in 2019)[18] and ease of doing business (from ranking 113th out of 155 countries in 2006 to rank 95th out of 190 countries in 2019)[19].

Figure 5. Sectoral share to total GDP (in %), 1998-2018

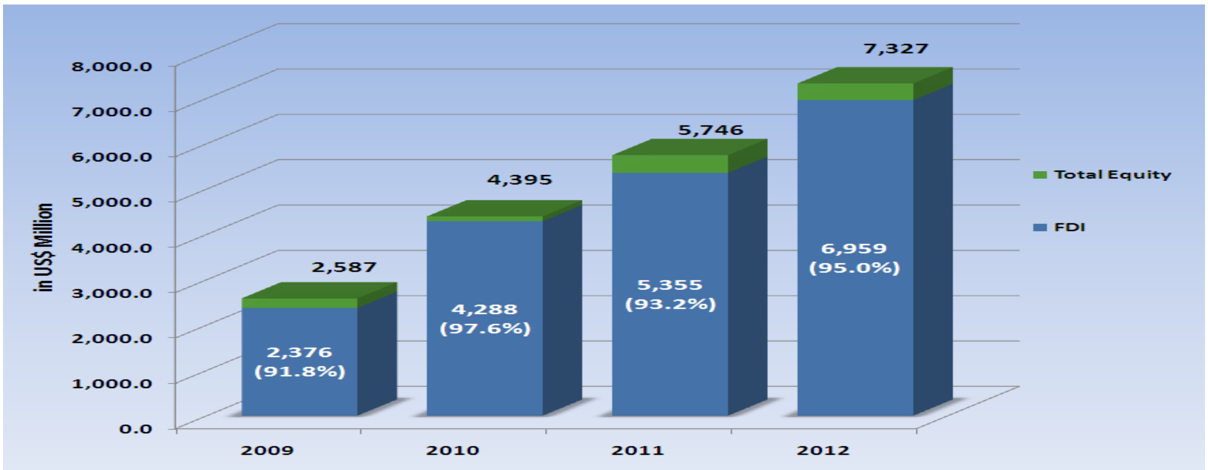


Source of raw data: National Accounts, Philippine Statistics Authority

[17] Philippine Statistics Authority: National Income Accounts and Current Labor Statistics
[18] World Economic Forum: Global Competitiveness Reports
[19] The World Bank: Ease of Doing Business Reports

Foreign direct investments (FDI) in the services sector are on an increasing trend mainly driven by investments in IT-BPO companies that strengthens service delivery in the financial services, logistics, engineering, software, media, human resources, healthcare, insurance, IT and legal industries. In 2012, FDI reached around US$ 7.0 billion, which reflects a 193 percent increase from the total FDI of US$ 2.4 billion in 2009 (Figure 6).

Figure 6. Share of FDI to total equity investments (in US$ million and percent share), 2009-2012

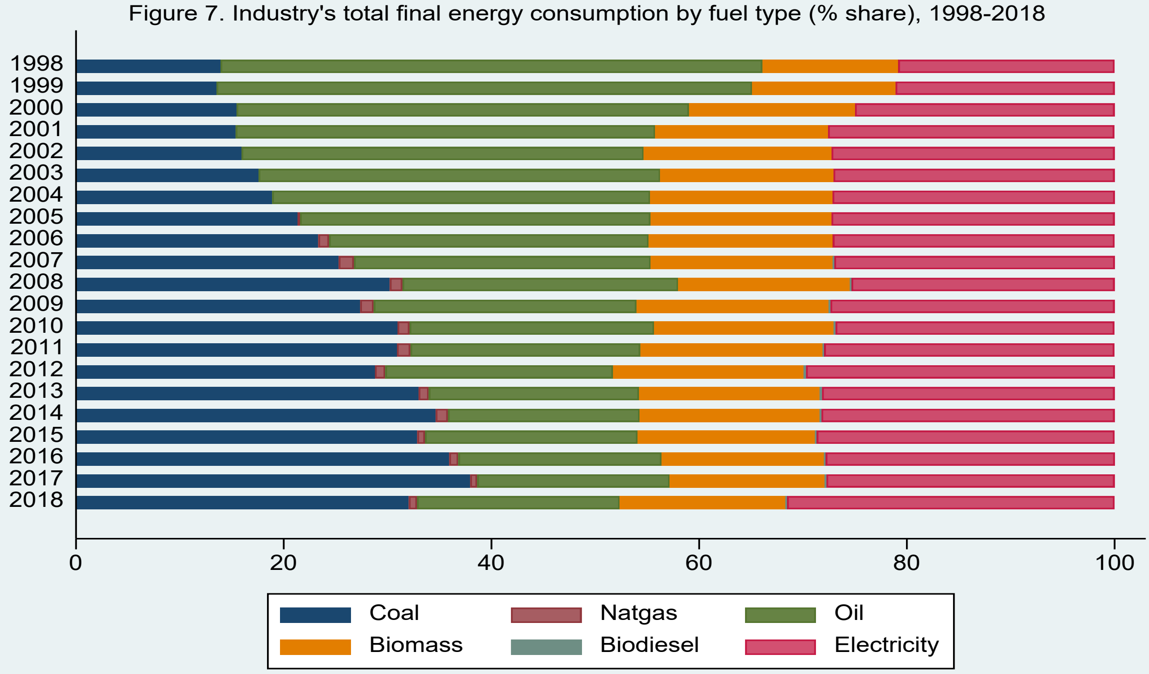


Source: Results of the Survey of IT-BPO Services, 2012, Bangko Sentral ng Pilipinas

For the industrial and TAFF sectors, no causality was found, which means that the GDP has no significant impact on electricity consumption and vice versa for these sectors in the short-run. Despite the robust economic growth taking place in the country, it was still unable to expand in the field of the industrial sector, which according to Chen et al. (2007), is one of the sectors where electricity has been the primary input of energy for expansion. The Philippines has not experienced rapid industrial growth led by manufacturing, unlike our neighboring countries (i.e., Thailand, Indonesia, Malaysia). The industry sector's share to GDP is almost constant at 34 percent for the past two decades (Figure 5) with the manufacturing sector, on average, accounting for 23 percent of the GDP in the last twenty years. The same slow-growth scenario can be observed in the TAFF sector, with growth averaging to only 4.1 percent for the past twenty years, while its share to total GDP declined from 20 percent in 1999 to 15 percent in 2019.[20]

Looking at the other side of causation, electricity consumption does not cause GDP in these sectors, mainly because the industry sector is energy-intensive and is heavily dependent on coal, oil, and biomass rather than electricity for production (Figure 7), although we can notice an increasing share of electricity in recent years. The TAFF, on the other hand, relies strongly on oil, particularly diesel, as shown in Figure 8. Besides, the roll-out of e-vehicles in the Philippines has been slow, and the interest from players has been weak despite the current projects of the government to boost the use of e-vehicles in the country.[21] The electricity consumption in these sectors is not enough to trigger significant deviations in the country's economic growth – both as a contributory and limiting factor.

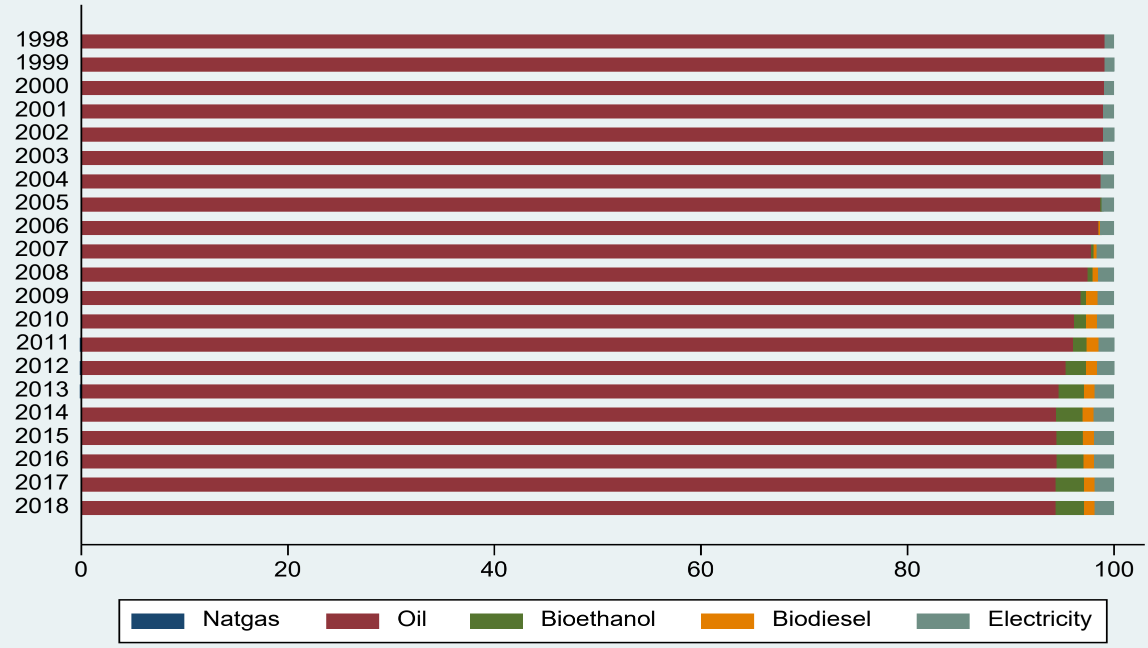
Figure 7. Industry's total final energy consumption by fuel type (% share), 1998-2018



Source of raw data: Key Energy Statistics, Department of Energy

[20] Philippine Statistics Authority: National Income Accounts
[21] https://www.rappler.com/business/233944-department-trade-industry-program-boost-electric-vehicle-investments-philippines

Figure 8. TAFF's total final energy consumption by fuel type (% share), 1998-2018

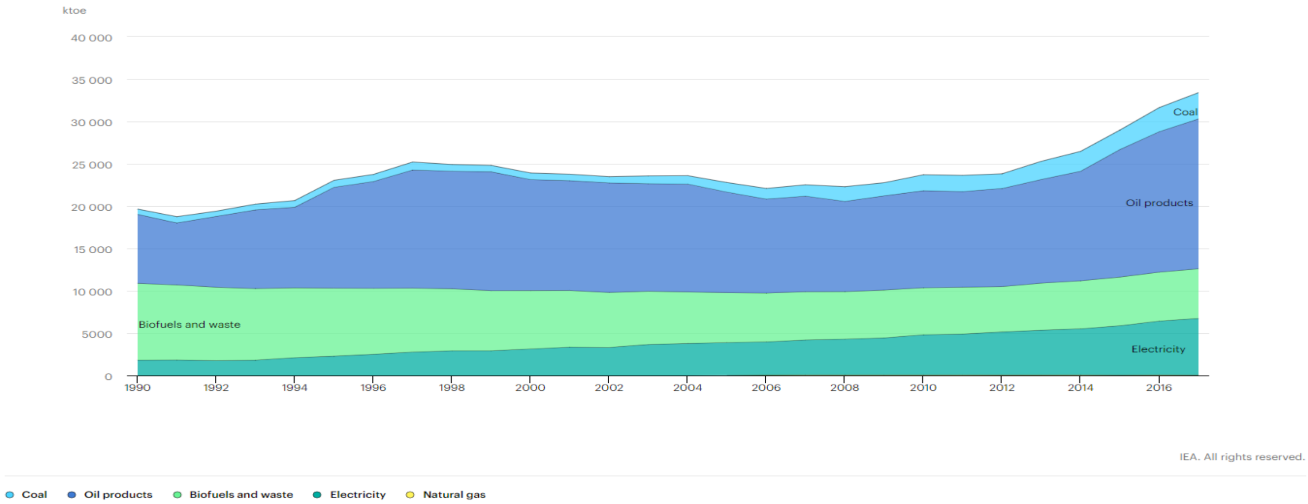


Source of raw data: Key Energy Statistics, Department of Energy

In the long run, the study found evidence on the existence of bi-directional causality between economic growth and electricity consumption for all the sectors combined. In other words, a simultaneous increase in GDP and electricity consumption can be observed, which implies that productive activities in the country need electricity not just an input for production but also as an engine for economic growth. Demand for electricity significantly increased by 267 percent in 2017 from 1824 kTOE in 1990[22] (Figure 9) and is projected to increase more rapidly in the next twenty years (Figure 10).

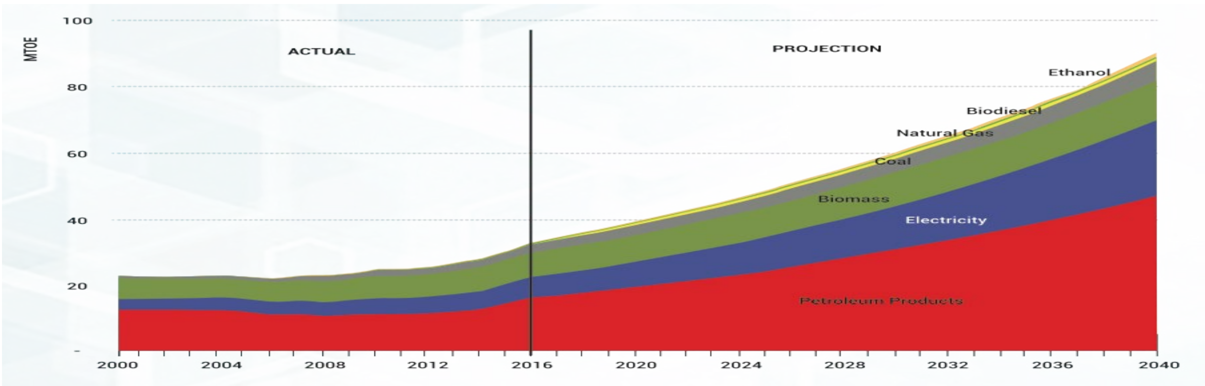
[22] International Energy Agency: World Energy Balances 2019

Figure 9. Total final energy consumption by source (in kTOE), 1990-2017



Source: World Energy Balances 2019, International Energy Agency

Figure 10. Projected total final energy demand by source (in kTOE), 2017-2040



Source: Philippine Energy Development Plan 2017-2040, Department of Energy

As the Philippines advances to further developments, electrification, digitization and decentralization will be a critical factor in the expansion and development of the existing and emerging markets in the country, which would consequently contribute to a sustained robust economy in the long run.

The findings of this empirical research complemented the result of bidirectional causality between economic growth and electricity consumption in other developing countries (Soytas and Sari, 2003; Yoo, 2006; Wolde-Rufael, 2006; Odhiambo, 2009; Oedraogo, 2010). In the same way, despite the disparity on the level of development, the findings for the Philippines was consistent with that of some developed countries such as in Portugal, Venezuela, Japan, Italy, France, Korea, and Germany, among others (Shahbaz et al., 2011; Yoo and Kwak, 2010; Lee, 2004; Guttormsen, 2004).

5. SUMMARY, CONCLUSION AND POLICY IMPLICATIONS

This study contributed to the existing literature by investigating the short-run causal link on a sectoral level and long-run causal link at the aggregate level between electricity consumption and economic growth in the Philippines. The ARDL-ECM PMG estimation was applied to determine the presence of a short-run and long-run relationship, as well as the causal direction between the variables in the sectoral and aggregate level using data from 1998 to 2018.

The empirical results confirm the existence of a short-run relationship running from economic growth to electricity consumption in the commercial and residential sectors. In contrast, the results for the industrial and TAFF sectors support the neutral hypothesis, which means there is no causality between economic growth and electricity consumption in the short-run. In the long-run, the study found evidence in support of the feedback hypothesis or a bidirectional causality between economic growth and electricity consumption for all the sectors combined. The results of this study have several important policy implications for the Philippines.

First, the COVID-19 pandemic has brought unexpected and unprecedented global socioeconomic shock that forced countries around the world to implement drastic changes and restrict both social and economic activities to control the spread of the coronavirus. These include partial and complete lockdown, closure of non-essential business establishments and educational institutions, curfews, and prohibition of social gatherings. As a result, governments and societies across the world were compelled to shift to alternative methods (i.e., telecommuting, online education platforms, online market, etc.), which depend heavily on stable and reliable electricity supply in keeping the economy afloat, healthcare system functioning, and businesses running. The pandemic has underscored how the country is highly reliant on electricity to function and has put greater emphasis on the important role that electricity plays both in stimulating economic growth and sustaining our daily life.

As the Philippines transitions to a post-pandemic stage or a "new normal," higher electricity consumption will be expected as production and commercial sectors shift to digital transactions, automation, use of modern machinery, among others. In the agriculture and fishery sector, demand for modern agricultural machinery and equipment is anticipated to increase to reduce the need for manual labor. Innovative technologies will also be highly demanded for storage and for processing of food with longer shelf life, as well as modernizing the food supply chain and logistics. The use of digital technology will also be maximized to link customers and producers through various online platforms. For the industry sector, there will be a faster shift to the automation of production processes. There will also be an increased need for investments in data infrastructure to accelerate deployment of AI and IoT technologies in maximizing efficiency and enhancing the flexibility of both the supply chain and manufacturing operations. The government might also explore the revival and strengthening of domestic manufacturing for national resilience, which will require sufficient, reliable, and affordable electricity to attract investors. In the commercial sectors, flexible work arrangements will have to be implemented, and, in many instances, virtual interaction will emerge to be a key part of the business processes. E-commerce is also expected to boom as retailers open virtual stores online and collaborate with marketplace platforms. This will also expand the use of cashless payment system and other online financial platforms (National Economic and Development Authority, 2020). The residential sector's electricity consumption is also anticipated to increase further as people spend more time at home while doing work and education-related activities. Thus, further investments in electricity supply infrastructure and networks will be crucial in the "new normal." As implied by Baer et al. (2002), the gain brought by increased usage of ICTs to the economy will only be realized if there is a robust national electricity infrastructure that provides support to ICT adoption and applications.

Considering the foregoing, we can expect that a higher bidirectional causality between economic growth and electricity consumption could emerge in the post-pandemic "new normal." Policies towards an affordable, stable, reliable, efficient, and sustainable electricity is essential to be part of the country's economic recovery and stimulus package. This will be important in supporting and facilitating the enhanced digitalization and electrification, modernization of machinery and equipment, increased technological and financial innovation, expanded use of e-commerce, and flexible work arrangements needed both in the short- and long-run.

Second, the findings imply that there is a strong need to improve energy (electricity) efficiency across all sectors both in the short and long-run. A survey conducted by JICA in 2012 cited the lack of available and accessible financial mechanisms, lack of household awareness on the importance and benefits of energy (electricity) efficiency, minimal knowledge of businesses on the government's initiatives and programs on energy (electricity) efficiency, and the absence of strong legal and institutional framework to enforce energy (electricity) measures as among the bottlenecks in the country's efforts to improve energy (electricity) efficiency. Thus, policies and reforms should be implemented for the government: (1) to create financial mechanisms for all sectors to be able to support and encourage businesses to shift to non-traditional operations by investing in and developing electricity-saving technologies and processes as well as support the households in implementing energy (electricity) efficiency measures, (2) to implement initiatives aimed at encouraging behavioral change of businesses and households, and (3) to institutionalize energy (electricity) efficiency directives.

Financial mechanisms must continue to be in place and be expanded to encourage not only the businesses but also the households to invest in energy-efficient technologies and measures. It is also important that these financial mechanisms be made accessible, and the application process is streamlined and simplified. The national government can also explore opportunities for partnership with private financial institutions in improving and expanding financial mechanisms available for businesses and households (e.g., lower interest rates and longer payment terms of loans from private banks for investments on energy (electricity) improvements, etc.). This will also help private financial institutions to be able to incorporate environmental, social, and governance standards in their corporate governance and strategic operations. Financial incentive schemes such as subsidies and zero or reduced value-added tax can also be considered to enhance the purchase of highly efficient products and replace old products that are below efficiency standards.

Financial mechanisms must also be complemented with adequate information campaigns to raise the awareness of businesses, especially the micro, small, and medium enterprises, and the households of the available financial resources and incentives that they can tap into implementing energy (electricity) efficient activities and measures. Moreover, energy (electricity) awareness of Filipinos must also be increased through seminars and training, intensive information campaigns in social media, information dissemination through the local government units, among others, to promote behavioral change. The incorporation of energy efficiency courses in the curriculum for primary and secondary education should also be sought after to encourage behavioral change and reinforce principles of sustainable development.

It is also necessary to institutionalize energy (electricity) efficiency directives to ensure continuity and inclusion across different administrations' socioeconomic agenda. This can be done by integrating energy (electricity) efficiency in the mainstream of energy policy through the development of a long-term National Energy Efficiency and Conservation Plan (NEECP) that will complement the existing Philippine Energy Plan 2017-2040. The NECP should also be considered in the succeeding Philippine Development Plans and, more importantly, in the Regional Development Plan to ensure active local government unit (LGU) and private sector participation. Furthermore, programs and policies to promote, encourage, and support the use of electric vehicles (EV) must also be mainstreamed and integrated into the national plans stated above to strengthen the sustainability of the automotive industry and establish a transportation environment that is economically and energy-efficient as well as environmentally sound.

The enactment of the Energy Efficiency and Conservation Act in 2019 is a first step towards institutionalizing fundamental policies on effective conservation and efficient consumption of the country's limited energy resources. However, the success of this measure highly depends on the effective management of the implementing rules and regulations. An annual performance monitoring and evaluation framework must be established and implemented by the Department of Energy to ensure continuous improvement and effectiveness of the law. Another important aspect to be considered in the institutionalization of energy efficiency in the country is the availability of energy efficiency and management data in different sectors. Currently, energy consumption by fuel source is available in four sectors, namely commercial, industrial, residential, and TAFF; however, there is insufficient data in commercial and industrial sub-sectors. Having adequate data per each sub-sector will be necessary for analysis, benchmarking, and forecasting as well as creating a more sector-specific or targeted policy approach.

Third, electricity rates in the Philippines are also one of the highest among its ASEAN neighbors[23] because the electricity rates in the country are "fully cost-reflective," unlike in other ASEAN countries such as Indonesia, Malaysia, and Thailand, where the government provides electricity rate subsidies. However, it should be noted that continued high electricity rates in the long-run can discourage electricity consumption that will adversely affect economic growth due to the bidirectional causality between the two variables. It is, therefore, necessary to have policies in place that will ensure stable and affordable electricity rates, especially as the country transitions to further digitalization and electrification while pursuing energy security and environmental sustainability.

Aside from the lack of government subsidy, the high electricity rates are also caused by the country's high dependence on imported fossil fuels. In addition, the current power supply agreements allow for the "pass-through provision," which permits power producers and distributors to simply pass fuel cost and foreign exchange fluctuations to consumers. A study conducted by Institute for Energy Economics and Financial Analysis (IEEFA) in 2019 found that the variations on imported coal prices can range from Php 2.00 per kWh to Php 7.11 per kWh above the agreed price in the power supply agreements (PSA). This caused consumers to pay Php 788.7 million (from May 2018 to May 2019) over the estimated cost in the PSA. The "pass-through provision" has led to a lack of diligence and inefficiencies in procuring imported fuels, which consequently lead to higher power generating costs. On top of this, consumers also pay three universal charges to pay for stranded contract costs[24] (Php 0.1938 per kWh), missionary electrification[25] (Php 0.1561

[23] https://digitalenergyasia.com/competitive-indonesian-electricity-rates-in-the-asean-region/
[24] Stranded Contract Cost of NPC refers to the excess of the contracted cost of electricity under eligible IPP contracts of NPC over the actual selling price of the contracted energy output. (Source: MERALCO)
[25] Missionary Electrification Charge is a universal charge to fund the electrification of remote and unviable areas, as well as areas not connected to the transmission system. (Source: MERALCO)

per kWh), and environment charge[26] (Php 0.0025 per kWh).

The government must level the playing field to spur competition and lower electricity rates by implementing legal, institutional, and market reforms as well as maximizing the RE potential in the country, especially for missionary electrification. Legal reforms to remove the "pass-through provision" in PSAs should be sought to reduce moral hazard and encourage power suppliers and distributors to hedge against price and currency unpredictability. This should also be complemented with institutional reforms that will pave the way for a more transparent and competitive auction for the procurement of power purchases, which will ensure the lowest possible cost option for power generation (IEEFA, 2019).

Policies to lower the universal charges being passed on to consumers should also be prioritized to lower electricity rates. The Murang Kuryente Act, which will reduce electricity rates by relieving consumers of the universal charges[27] (amounting to Php 0.86 kWh) through the allocation of Php 208 billion from the government's share in the Malampaya Fund, should be effectively implemented. This is important to ensure the translation of annual savings amounting to Php 2,580 for households who consume around 250 kWh per month on average. In the long-run, the country must also maximize its RE potential and take advantage of the decreasing prices of solar PV and wind technologies to provide electricity in off-grid areas and step away from the use of diesel and bunker fuel-fired power plants for missionary electrification. Modernization of small grids, R&D and investments for storage, as well as improvements in the distribution system in off-grid areas must also be pursued to enable higher penetration of variable RE while maintaining

[26] Environmental Charge is a universal charge that accrues to an environmental fund, which is used solely for watershed rehabilitation and management. This fund is managed by the National Power Corporation (NPC) and is pegged at PhP0.0025 per kWh. (Source: MERALCO)

[27] The act gives consumers relief from paying the stranded contract cost and stranded debt universal charges. Stranded debt consists of those unpaid National Power Corporation's financial obligations which have not been liquidated by the proceeds from the sales and privatization of its assets. (Source: https://www.bworldonline.com/energy-finance-depts-release-implementing-rules-for-murang-kuryente-act/)

system reliability, and prepare for the interconnection of small grids into the main grid in the long-run, which will consequently lower the universal charges.

Furthermore, establishing an efficiency standard for existing and new thermal powerplants will also contribute to the country's energy efficiency initiatives and will therefore lower fuel costs. The Philippines can learn from the Japanese experience in advocating for energy efficiency both on the producer and consumer side. Tapping the Japanese expertise through the JCM or other technical development assistance will not only help the country address energy efficiency bottlenecks but will also further the bilateral relationship between the two countries.

Legal and institutional market reforms towards a more competitive and transparent market for power generation, coupled with clean fossil fuel technologies and RE sources, will decrease the power generation costs, which makes up for 55% of the total electricity rate. Expanding, updating, and making power systems and infrastructure networks more flexible and resilient will also reduce transmission and distribution losses and costs, which makes up for around 30% of the total electricity rate. In addition, global fossil fuel costs have been declining since 2019, and the decline in prices has become even more drastic with the emergence of the COVID-19 pandemic, which resulted in a large scale reduction in global demand as a consequence of lockdown measures implemented across countries. The current low fossil fuel costs may continue over the short- to medium-run and may harm the relative competitiveness of RE sources over the traditional power sources. This may also possibly hamper the expansion of RE sources for power generation in the country. Although the impact of prolonged lower fossil fuel prices to the investments and deployment of RE sources as well as the effect of these global price developments in the country's electricity rates is beyond the scope of this study, it is important to highlight that the government must continue to strive for a well-balanced electricity mix and at the same time continuously pursue energy policies and investments that will lead to the better integration of energy security, economic efficiency, and environmental protection or the "3Es".

Fourth, as of 2018, the Philippines' power mix is still dominated by fossil fuel accounting for more than 50 percent of the total power generation while renewable energy (REs) only accounts for 23.4 percent, with geothermal and hydro accounting for the bulk of the share.[28] Given the country's high dependence on fossil fuel for power generation, it would also be crucial to mitigate environmental damage of the expected higher electricity consumption alongside economic growth.

Increasing the share of RE sources and technology for power generation in the country is essential in diversifying the primary energy supply mix, increasing energy security by reducing import dependency on fossil fuels, and achieving the country's nationally determined contributions pursuant to the Paris Agreement. The country should take advantage of the decreasing RE prices, particularly for wind and solar, by complementing the existing RE programs and projects (i.e., FIT, net metering, renewable portfolio standards, etc.) with improved business climate and more efficient and streamlined processes to attract local and foreign investors in RE power generation and clean development mechanism projects. Moreover, the Ease of Doing Business Act of 2018 should be strictly implemented and assessed annually to ensure compliance from all stakeholders.

RE, including variable sources such as solar PV and wind, will be essential for the country to ensure sustainable energy and minimize environmental impacts. And as the capital costs of solar and wind technologies continue to decline and become more economically viable, these technologies will be important in increasing the current power

[28] Department of Energy, 2018 Power Statistics

supply capacity to meet the growing demand for electricity, supporting further economic growth, and achieving the country's vision for an environmentally sustainable energy sector. However, the country must proactively prepare the power sector for the impact of higher variable RE penetration in the system, particularly the increasing balancing cost associated with the integration of these technologies into the grid. This means that as the share of variable RE increases, frequent fluctuations in generation can be expected, which increases system requirements for balancing power supply and demand.

Effective grid integration methods can maximize the cost-effectiveness of integrating variable RE to the power system without losing its stability and reliability. Methods include increased system flexibility and long-term power system development planning with a greater focus on increased variable RE levels in total power generation, among others (National Renewable Energy Laboratory (NREL), 2015). In terms of increasing system flexibility, institutional changes prove to have low capital costs and the least expensive variable RE integration option (NREL, 2015).

Thus, the government must consider and give importance to the necessary changes needed in the system operations and market design to accommodate increased variable RE penetration in the system. This includes faster implementation of shorter market scheduling intervals or intra-hour dispatch in the Wholesale Electricity Spot Market (from the current hourly dispatch), capacity building for advance forecasting of power generation from solar and wind, and earlier availability and implementation of the ancillary service market to enable the co-optimization of energy and ancillary services (primary, secondary and tertiary reserves). The ancillary services market, however, needs to adapt to the changing power system landscape taking into account the expected increase in variable RE deployment. Innovative ancillary services will thus, be necessary to increase system flexibility and help address the variability and uncertainty in the grid (IRENA, 2019). The government can explore opening the ancillary services market to new participants, such as large-scale variable RE generators, and complement the services currently provided by conventional generators. In many countries, including the Philippines, variable RE technologies have been neglected when it comes to providing ancillary services; however, recent technological advancements have allowed variable REs to have additional ancillary services capabilities. A study conducted by IRENA (2019) showed the possibilities of wind turbines to provide inertial response while solar PV can provide reactive power support or voltage control. Current institutional measures being implemented in the country may need to be updated to accommodate new providers of ancillary services and encourage variable RE generators to have the technical capabilities to provide the additional services. In this regard, the government can also consider "grid-aware incentives" to reward and encourage variable RE generators to combine innovative technologies and processes in their operations and contribute to grid stability and reliability (NREL, 2015). This will not only encourage RE investments but also reduce the cost and uncertainties brought by variable RE integration to the grid.

The country also has a lot of potential in reducing GHG emissions (Mondal et al., 2018); thus, the government can also leverage existing international relations such as the Joint Crediting Mechanism (JCM) partnership with Japan. This partnership can increase renewable energy and low-carbon products, systems, services, and infrastructure in the country and, at the same time, contribute to Japan's achievement of their GHG emission reduction targets. The country can also tap on development partners for technical cooperation to increase the country's capacity for planning, operating, maintaining, and governing the power system in anticipation of higher shares of variable RE in the power mix. Capacity building can help relevant institutions and stakeholders (e.g., system operators, generators, regulators, etc.) learn from best practices and be equipped with necessary skills and latest tools on power system operations and forecasting with medium to high variable RE penetration. This will help the country adapt to the fast-changing power system landscape, and better prepare the power sector as an instrument to not only support but also stimulate higher economic growth.

Lastly, it is also important to complement the policies towards a green economy with adequate, reliable, and resilient power infrastructure networks. Power infrastructure network expansion must be accelerated to meet the structural changes in the power sector and accommodate anticipated capacity additions from RE and alternative fuel sources. Transmission networks' capacity needs to be improved to adapt to the increased power supply and maximize the power generation from REs, particularly Solar PV and wind. The Department of Energy (DOE) and the National Grid Corporation of the Philippines (NGCP) must establish greater cooperation to ensure that power development plans and the outlook is balanced with and supported by strategic and sufficient transmission networks. Stronger coordination and planning between the DOE and NGCP can reduce the cost of investments of additional transmission networks needed to integrate increased variable RE into the grid. An intensive study should be made to model or identify best locations for additional RE generation capacity expansion considering access to transmission networks, availability and quality of potential RE sources, demand for electricity, and land ownership. This is crucial to address the issues related to frequent solar energy curtailments that happened in the Visayas Region between 2014-2016 due to transmission line congestions (NGCP, 2016). This will also help prevent excessive development of RE sources on areas or regions without ample power demand and sufficient transmission capacity to use RE generation efficiently.

The country is also prone to weather disturbances and natural calamities; thus, it is critical to not only establish traditional power network infrastructures but also invest in resilient network layouts such as decentralized storage and underground cables, among others. The on-time completion of the Philippine One Grid is also crucial to stabilize and fill in the supply shortages in the Mindanao region, the second-largest island of the country. The lack of adequate and reliable power supply in Mindanao is considered as one of the most binding constraints to the region's growth and development. Thus, addressing the power infrastructure shortage in Mindanao will help meet the expected increase in electricity demand. It will also open new investment priorities that will help tap the region's potential for higher economic growth and development as well as contribute to the country's overall sustainable and inclusive development agenda.

This study presented various policy perspectives that highlighted the importance of pursuing electricity security both in the short and long run as well as the need for the government's commitment to clean energy transition and improved energy efficiency while maintaining affordable electricity rates in expanding economic growth and in moving towards a more sustainable future for all.

Although the results of this study extended the existing literature in the Philippines by determining the causal impact between economic growth and electricity consumption in the sectoral and aggregate level, there are limitations in scope and therefore has several possibilities to improve the study through further research. First, the period of observation has been limited to twenty years due to the lack of comparable and disaggregated economic growth data for the services and residential sectors. To compensate for the limitation on the number of observed samples, further research can complement the results of the study by extending the analysis to include regional data to develop a region-specific policy perspective for the power sector. Second, it would also be interesting to see the causal relationship between economic growth and electricity consumption by the power source. Knowing the causality direction by each power source will help policymakers develop a specific roadmap per source with caution and a more explicit policy direction. Third, researchers can also do a more focused and sector-specific study by analyzing the causality between economic growth and the manufacturing and/or commercial sub-sectors. Lastly, future research can improve the study by adding variables to the current equation and determine the causal relationship between economic growth per capita, employment, electricity consumption, electricity rates, and carbon emissions.

References:

Acaravci, A., Ozturk, I., 2010. Electricity consumption–growth nexus: evidence from panel data for transition countries. *Energy Economics* 32, 604–608.

Adom, P., 2011. Electricity Consumption-Economic Growth Nexus: The Ghanaian Case. *International Journal of Energy Economics and Policy* 1. 18-31.

Akinlo, A.E., 2009, "Electricity Consumption and Economic Growth in Nigeria: Evidence from Cointegration and Co-feature Analysis", *Journal of Policy Modeling* 31, 681–693.

Akkemik, K.A., Goksa, K. 2012. Energy consumption-GDP nexus: Heterogenous panel causality analysis. *Energy Economics* 34. 865-873.

Altinay, G., Karagol, E., 2005. Electricity consumption and economic growth: Evidence from Turkey. *Energy Economics* 27, 849–856.

Apergis, N., Payne, J.E., 2009. Energy consumption and economic growth in Central America: evidence from a panel cointegration and error correction model. *Energy Economics* 31, 211–216.

Apergis, N., Payne, J. E., 2011. A dynamic panel study of economic development and the electricity consumption-growth nexus. *Energy Economics 33*, 770-781.

Asafu-Adjaye, J., 2000. The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. *Energy Economics* 22, 615-625

Aqeel, A., Butt, M.S., 2001. The relationship between energy consumption and economic growth in Pakistan*. Asia Pacific Development Journal* 8, 101–110.

Bacon, Robert. 2019. Learning from Power Sector Reform : The Case of The Philippines. Policy Research Working Paper; No. 8853. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/31711 License: CC BY 3.0 IGO.

Bildirici, M., 2012. The relationship between economic growth and energy consumption. *Journal of Renewable and Sustainable Energy* 4. 10.1063/1.3699617.

Blanchard, O., 2010. *Macroeconomics Updated Edition* (5th Edition ed.). Pearson Education South Asia Pte. Ltd.

Chandran, V.G.R., Sharma, S., Madhavan, K., 2010. Electricity consumption–growth nexus: the case of Malaysia. *Energy Policy* 38, 606–612.

Chen, S.T., Kuo, H.I., Chen, C.C., 2007. The relationship between GDP and electricity consumption in 10 Asian countries. *Energy Policy* 35, 2611–2621.

Chien-Chiang Lee, C.-P. C., 2007. Energy consumption and GDP revisited: A panel analysis of developed and developing countries. *Energy Economics 29* , 1206–1223.

Ciarreta, A., Zarraga, A., 2010. Economic growth–electricity consumption causality in 12 European countries: a dynamic panel data approach. *Energy Policy* 38, 3790–3796.

Dahmardeh, N., Mahmoodi, M., Mahmoodi, E., 2012. Energy Consumption and Economic Growth: Evidence from 10 Asian Developing Countries. *Journal of Basic and Applied Scientific Research* 2(2), 1385-1390

Dantama, Y. U., Y. Z. Abdullahi, and N. Inuwa. 2011. Energy Consumption— Economic Growth Nexus in Nigeria: An Empirical Assessment Based on ARDL Bound Test Approach. *European Scientific Journal* 8:12.

Engle, R.F., Granger, C.W.J., 1987. Co-integration and error correction: representation, estimation and testing. *Econometrica* 55, 251-276

Erdal, G., Erdal, H., Esengun, K., 2008. The causality between energy consumption and economic growth in Turkey. Energy Policy 36. 3838-3842.

Ghosh, S., 2002. Electricity consumption and economic growth in India. *Energy Policy* 30, 125–129.

Granger, C.W.J., 1969. Investigating causal relationships by econometric models and cross-spectral methods. *Econometrica 37*, 424–438.

Gurgul, H., Lach, L., 2012. The electricity consumption versus economic growth of the Polish economy. *Energy Economics* 34. 500-510.

Guttormsen, A.G., 2004. Causality between energy consumption and economic growth. Discussion Paper #D-24-2004, Agricultural University of Norway.

Hanif, A., Ismali, A., Abd Rashid, A., 2017. Electricity Consumption and Economic Growth in ASEAN.

Ho, C.Y., Siu, K.W., 2007. A dynamic equilibrium of electricity consumption and GDP in Hong Kong: An empirical investigation. *Energy Policy* 35, 2507–2513.

Hu, J.L., Lin, C.H., 2008. Disaggregated energy consumption and GDP in Taiwan: A threshold cointegration analysis. *Energy Economics* 30, 2342–2358

International Energy Agency, 2018. The Year of Electricity at the IEA. Accessed March 10, 2020 from: https://www.iea.org/news/the-year-of-electricity-at-the-iea

Institute for Energy Economics and Financial Analysis, 2019. Prospects Improve for Energy Transition in the Philippines. Accessed May 14, 2020 from: https://ieefa.org/wp-content/uploads/2019/09/Prospects-Improve-for-Energy-Transition-in-the Philippines_September-2019.pdf

Institute for Energy Economics and Financial Analysis, 2019. The Philippine Energy Transition. Accessed May 16, 2020 from: https://ieefa.org/wp-content/uploads/2019/03/The-Philippine-Energy-Transition_March-2019.pdf

IRENA, 2017. *Adapting market design to high shares of variable renewable energy*. International Renewable Energy Agency, Abu Dhabi.

IRENA, 2019. *Innovation landscape brief: Innovative ancillary services*, International Renewable Energy Agency, Abu Dhabi.

IRENA, 2019. *Solutions to integrate high shares of variable renewable energy* (Report to the G20 Energy Transitions Working Group (ETWG)), International Renewable Energy Agency, Abu Dhabi.

Jamil, F., Ahmad, E., 2010. The relationship between electricity consumption, electricity prices, and GDP in Pakistan. *Energy Policy* 38 (2010). 6016-6025

Japan International Cooperation Agency, 2012. The Development Study on Energy Efficiency and Conservation in the Republic of the Philippines. Accessed April 13, 2020 from: https://openjicareport.jica.go.jp/pdf/12058228_01.pdf

Kouakou, Auguste K., 2011. Economic growth and electricity consumption in Cote d'Ivoire: Evidence from time series analysis. *Energy Policy* 39, (6), 3638-3644

Kraft, J., Kraft, A., 1978. On the relationship between energy and GNP. *Journal of Energy Development* 3, 401–403.

Lee, C.C., Chang, C.P., 2005. Structural breaks, energy consumption, and economic growth revisited: Evidence from Taiwan. *Energy Economics* 27, 857–872

Mozumder, P., Marathe, A., 2007. Causality relationship between electricity consumption and GDP in Bangladesh. *Energy Policy* 35, 395–402.

Masih, A.M.M., Masih, R., 1996. Energy consumption, real income and temporal causality; results from a multi-country study based on cointegration and error correction modelling techniques. *Energy Economics* 18, 165–183.

Masih, A.M.M., Masih, R., 1997. On temporal causal relationship between energy consumption, real income and prices; some new evidence from Asian energy dependent NICs based on a multivariate cointegration/vector error correction approach. *Journal of Policy Modeling* 19. 417–440.

Muhammad Shahbaz, M. Z. (2012). Is energy consumption effective to spur economic growth in Pakistan? New evidence from bounds test to level relationships and Granger causality tests. *Economic Modelling 29*, 2310–2319.

Narayan, P.K., Prasad, A., 2008. Electricity consumption–real GDP causality nexus: evidence from a bootstrapped causality test for 30 OECD countries. *Energy Policy* 36, 910–918.

Narayan, P.N., Singh, B., 2007. The electricity consumption and GDP nexus for the Fiji Islands. *Energy Economics* 29, 1141–1150.

Narayan, P.K., Smyth, R., 2005. Electricity consumption, employment, and real income in Australia: evidence from multivariate Granger causality tests. *Energy Policy* 33, 1109– 1116.

Narayan, P.K., Smyth, R., 2009. Multivariate granger-causality between electricity consumption, exports, and GDP: evidence from a panel of Middle Eastern countries. *Energy Policy* 37, 229–236.

National Economic and Development Authority, 2020. We Recover As One. Accessed May 29, 2020 from: http://www.neda.gov.ph/wp-content/uploads/2020/05/We-Recover-As-One.pdf

National Grid Corporation of the Philippines, 2015. Transmission Development Plan 2014-2015: Consultation Draft. Volume 1. Accessed March 15, 2019 from: http://www.ngcp.ph/beta/cms/Attachment-Uploads/TDP_2014-2015_Vol_I%20-_Draft.pdf.

National Renewable Energy Laboratory, 2015. Integrating Variable Renewable Energy into the Grid: Key Issues. Accessed May 7, 2020 from: https://www.nrel.gov/docs/fy15osti/63033.pdf

Odhiambo, N.M., 2009. Electricity consumption and economic growth in South Africa: a trivariate causality test. *Energy Economics* 37, 617-622

Ouédraogo, I., 2010. Electricity consumption and economic growth in Burkina Faso: A cointegration analysis. *Energy Economics* 32, 524-531.

Oh, W., Lee, K., 2004. Causal relationship between energy consumption and GDP revisited: the case of Korea 1970–1999. *Energy Economics* 26, 51–59.

Ozturk, I., Acaravci, A., 2010. The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary, and Romania: evidence from ARDL bound testing approach. *Applied Energy* 87, 1938–1943

Pao, Hsiao-Tien. (2009). Forecast of electricity consumption and economic growth in Taiwan by state space modeling. *Energy 34*.

Republic Act No. 11285 An Act Institutionalizing Energy Efficiency and Conservation, Enhancing the Efficient Use of Energy, and Granting Incentives to Energy Efficiency and Conservation Projects. (2019 & Supp. 2020)

Republic Act No. 11471 An Act Reducing Electricity Rates by Allocating a Portion of the Net National Government Share from the Malampaya Natural Gas Project for the Payment of the Stranded Contract Costs and Stranded Debts. (2019 & Supp. 2020)

Soytas, U., Sari, R., 2003. Energy consumption and GDP: causality relationship in G-7 countries and emerging markets. *Energy Economics* 25, 33–37

Shiu, A., Lam, P.L., 2004. Electricity consumption and economic growth in China. *Energy Policy* 32, 47–54.

Squalli, J., 2007. Electricity consumption and economic growth: bounds and causality analyses of OPEC countries. *Energy Economics* 29, 1192–1205.

Tang, C.F., 2008. A re-examination of the relationship between electricity consumption and economic growth in Malaysia. *Energy Policy* 36, 3077–3085.

Tang C.F., Shahbaz M., 2008. Sectoral analysis of the causal relationship of electricity consumption and real output in Pakistan. *Energy Policy* 60. 885-891

Wen-Cheng Lu, 2016. Electricity Consumption and Economic Growth: Evidence from 17 Taiwanese Industries. *Sustainability*. 9. 50. 10.3390/su9010050.

Wolde-Rufael, Y., 2004. Disaggregated industrial energy consumption and GDP: the case of Shanghai, 1952–1999. *Energy Economics* 26, 69–75

Wolde-Rufael, Y., 2006. Electricity consumption and economic growth: a time series experience for 17 African countries. *Energy Policy* 34, 1106–1114.

Yoo, S.H., 2005. Electricity consumption and economic growth: evidence from Korea. *Energy Policy* 33, 1627–1632.

Yoo, S.H., 2006. The causal relationship between electricity consumption and economic growth in the ASEAN countries. *Energy Policy* 34, 3573–3582.

Yoo, S.H., Kim, Y., 2006. Electricity generation and economic growth in Indonesia. *Energy* 31, 2890–2899.

Yoo, S.H., Kwak, S.Y., 2010. Electricity consumption and economic growth in seven South American countries. *Energy Policy* 38, 181–188

Yuan, J., Zhao, C., Yu, S., Hu, Z., 2007. Electricity consumption and economic growth in China: cointegration and co-feature analysis. *Energy Economics* 29, 1179–1191

Appendix

Appx. 1 Unit Root Tests

```
Levin-Lin-Chu unit-root test for logGDP
───────────────────────────────────────
Ho: Panels contain unit roots           Number of panels  =      4
Ha: Panels are stationary               Number of periods =     21

AR parameter: Common                    Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 8.00 lags average (chosen by LLC)
──────────────────────────────────────────────────────────────────────────────
                    Statistic      p-value
──────────────────────────────────────────────────────────────────────────────
 Unadjusted t        -2.9872
 Adjusted t*         -0.9861        0.1620
──────────────────────────────────────────────────────────────────────────────

Levin-Lin-Chu unit-root test for logEC
──────────────────────────────────────
Ho: Panels contain unit roots           Number of panels  =      4
Ha: Panels are stationary               Number of periods =     21

AR parameter: Common                    Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 8.00 lags average (chosen by LLC)
──────────────────────────────────────────────────────────────────────────────
                    Statistic      p-value
──────────────────────────────────────────────────────────────────────────────
 Unadjusted t        -3.6227
 Adjusted t*          0.1115        0.5444
──────────────────────────────────────────────────────────────────────────────

Levin-Lin-Chu unit-root test for D.logGDP
─────────────────────────────────────────
Ho: Panels contain unit roots           Number of panels  =      4
Ha: Panels are stationary               Number of periods =     20

AR parameter: Common                    Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 8.00 lags average (chosen by LLC)
──────────────────────────────────────────────────────────────────────────────
                    Statistic      p-value
──────────────────────────────────────────────────────────────────────────────
 Unadjusted t        -6.7935
 Adjusted t*         -2.5103        0.0060
──────────────────────────────────────────────────────────────────────────────
Levin-Lin-Chu unit-root test for D.logEC
────────────────────────────────────────
Ho: Panels contain unit roots           Number of panels  =      4
Ha: Panels are stationary               Number of periods =     20

AR parameter: Common                    Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 8.00 lags average (chosen by LLC)
──────────────────────────────────────────────────────────────────────────────
                    Statistic      p-value
──────────────────────────────────────────────────────────────────────────────
 Unadjusted t        -9.6368
 Adjusted t*         -4.3162        0.0000
──────────────────────────────────────────────────────────────────────────────
```

```
Im-Pesaran-Shin unit-root test for logGDP
-----------------------------------------
Ho: All panels contain unit roots           Number of panels  =      4
Ha: Some panels are stationary              Number of periods =     21

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 1 lag
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar              2.2277        0.9871
------------------------------------------------------------------------------

Im-Pesaran-Shin unit-root test for logEC
----------------------------------------
Ho: All panels contain unit roots           Number of panels  =      4
Ha: Some panels are stationary              Number of periods =     21

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 1 lag
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar              0.8638        0.8061
------------------------------------------------------------------------------
Im-Pesaran-Shin unit-root test for D.logGDP
-------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      4
Ha: Some panels are stationary              Number of periods =     20

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 1 lag
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -2.2251        0.0130
------------------------------------------------------------------------------
Im-Pesaran-Shin unit-root test for D.logEC
------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      4
Ha: Some panels are stationary              Number of periods =     20

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 1 lag
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -4.9114        0.0000
------------------------------------------------------------------------------
```

Appx. 2 Panel Cointegration Tests

```
Pedroni test for cointegration
------------------------------
Ho: No cointegration                        Number of panels       =      4
Ha: All panels are cointegrated             Number of periods      =     20

Cointegrating vector: Panel specific
Panel means:          Included              Kernel:           Bartlett
Time trend:           Not included          Lags:             1.00 (Newey-West)
AR parameter:         Panel specific        Augmented lags:   1
------------------------------------------------------------------------------
                                            Statistic         p-value
------------------------------------------------------------------------------
 Modified Phillips-Perron t                  -0.6087          0.2714
 Phillips-Perron t                           -2.2095          0.0136
 Augmented Dickey-Fuller t                   -3.2330          0.0006
------------------------------------------------------------------------------
```

```
Pedroni test for cointegration
------------------------------
Ho: No cointegration                         Number of panels       =      4
Ha: All panels are cointegrated              Number of periods      =     20

Cointegrating vector: Panel specific
Panel means:          Included               Kernel:           Bartlett
Time trend:           Not included           Lags:             0.00 (Newey-West)
AR parameter:         Panel specific         Augmented lags:   1
------------------------------------------------------------------------------
                                             Statistic         p-value
------------------------------------------------------------------------------
 Modified Phillips-Perron t                   -0.5666          0.2855
 Phillips-Perron t                            -2.1841          0.0145
 Augmented Dickey-Fuller t                    -2.9465          0.0016
------------------------------------------------------------------------------
```

Appx. 3 Hausman Test

```
Iteration 0:   log likelihood =  146.01435  (not concave)
Iteration 1:   log likelihood =  149.94546
Iteration 2:   log likelihood =  150.14898
Iteration 3:   log likelihood =  150.17548
Iteration 4:   log likelihood =  150.17552
Iteration 5:   log likelihood =  150.17552

Pooled Mean Group Regression
(Estimate results saved as pmg)

Panel Variable (i): id                           Number of obs      =         80
Time Variable (t): Year                          Number of groups   =          4
                                                 Obs per group: min =         20
                                                                avg =       20.0
                                                                max =         20

                                                 Log Likelihood     =   150.1755
------------------------------------------------------------------------------
    D.logEC |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ECT          |
      logGDP |   .7476365   .0283389    26.38   0.000     .6920932    .8031797
-------------+----------------------------------------------------------------
SR           |
         ECT |  -.3321087   .1696076    -1.96   0.050    -.6645335    .0003161
             |
      logGDP |
         D1. |   .3725357    .229619     1.62   0.105    -.0775093    .8225806
             |
       _cons |  -.3440785   .1703523    -2.02   0.043    -.6779628   -.0101941
------------------------------------------------------------------------------

Dynamic Fixed Effects Regression: Estimated Error Correction Form
(Estimate results saved as DFE)
------------------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ECT          |
      logGDP |   1.052694    .138688     7.59   0.000     .7808708    1.324518
-------------+----------------------------------------------------------------
SR           |
         ECT |    -.19286   .0780379    -2.47   0.013    -.3458114   -.0399086
             |
      logGDP |
         D1. |   .0929373   .3392307     0.27   0.784    -.5719427    .7578173
             |
       _cons |  -1.048183   .4932012    -2.13   0.034    -2.014839   -.0815262
------------------------------------------------------------------------------

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |      pmg          DFE         Difference          S.E.
-------------+----------------------------------------------------------------
      logGDP |    .7476365     1.052694       -.3050578        2.320593
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtpmg
            B = inconsistent under Ha, efficient under Ho; obtained from xtpmg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(1) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        0.02
                Prob>chi2 =      0.8954
```

Appx. 4 ARDL-ECM PMG Estimates

```
Iteration 0:   log likelihood =  146.01435  (not concave)
Iteration 1:   log likelihood =  149.94546
Iteration 2:   log likelihood =  150.14898
Iteration 3:   log likelihood =  150.17548
Iteration 4:   log likelihood =  150.17552
Iteration 5:   log likelihood =  150.17552

Pooled Mean Group Regression
(Estimate results saved as PMG)

Panel Variable (i): id                          Number of obs      =        80
Time Variable (t): Year                         Number of groups   =         4
                                                Obs per group: min =        20
                                                               avg =      20.0
                                                               max =        20

                                                Log Likelihood     =  150.1755
```

D.logEC	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ECT						
logGDP	.7476365	.0283389	26.38	0.000	.6920932	.8031797
id_1						
ECT	-.2037304	.1155338	-1.76	0.078	-.4301724	.0227116
logGDP						
D1.	.8215081	.343224	2.39	0.017	.1488014	1.494215
_cons	-.299985	.2184488	-1.37	0.170	-.7281369	.1281668
id_2						
ECT	-.8376623	.2155983	-3.89	0.000	-1.260227	-.4150973
logGDP						
D1.	-.0789578	.2451863	-0.32	0.747	-.5595141	.4015984
_cons	-.804408	.3442327	-2.34	0.019	-1.479092	-.1297244
id_3						
ECT	-.1751823	.1525293	-1.15	0.251	-.4741343	.1237697
logGDP						
D1.	.7108961	.3899219	1.82	0.068	-.0533368	1.475129
_cons	.0185793	.0654827	0.28	0.777	-.1097645	.1469231
id_4						
ECT	-.1118599	.1379122	-0.81	0.417	-.3821629	.1584431
logGDP						
D1.	.0366963	1.309298	0.03	0.978	-2.529481	2.602874
_cons	-.2905002	.4052705	-0.72	0.473	-1.084816	.5038155

```
Iteration 0:   log likelihood =  216.44316
Iteration 1:   log likelihood =  216.50725
Iteration 2:   log likelihood =  216.51618
Iteration 3:   log likelihood =  216.51619

Pooled Mean Group Regression
(Estimate results saved as PMG)

Panel Variable (i): id                          Number of obs      =        80
Time Variable (t): Year                         Number of groups   =         4
                                                Obs per group: min =        20
                                                               avg =      20.0
                                                               max =        20

                                                Log Likelihood     =  216.5162
```

D.logGDP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ECT						
logEC	1.474865	.0803995	18.34	0.000	1.317285	1.632446
id_1						
ECT	-.0982298	.0281729	-3.49	0.000	-.1534477	-.0430119
logEC D1.	.0763605	.1049039	0.73	0.467	-.1292474	.2819684
_cons	.1070834	.0885237	1.21	0.226	-.0664198	.2805866
id_2						
ECT	-.412877	.1612978	-2.56	0.010	-.7290148	-.0967392
logEC D1.	-.1200775	.1897113	-0.63	0.527	-.4919049	.2517499
_cons	.0156622	.316756	0.05	0.961	-.6051681	.6364925
id_3						
ECT	-.1127705	.0357503	-3.15	0.002	-.1828398	-.0427013
logEC D1.	-.0047732	.109058	-0.04	0.965	-.218523	.2089766
_cons	-.1248271	.0778821	-1.60	0.109	-.2774732	.0278191
id_4						
ECT	.0291795	.0144916	2.01	0.044	.0007764	.0575825
logEC D1.	.0473847	.0406466	1.17	0.244	-.0322812	.1270505
_cons	-.0494902	.0502258	-0.99	0.324	-.147931	.0489506