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Electricity Consumption and Economic Growth in Emerging Economies

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Emerging economies have grown much faster than the advanced countries during the past decades. This study investigates the relationship between economic growth and electricity consumption in the emerging economies during the period 1970-2011 by using Pedroni, Kao and Johansen co-integration tests and Granger causality tests. We found that electricity consumption had a positive impact on the economic growth and there was bidirectional causality between economic growth and electricity consumption.

Keywords: *Emerging Economies, Economic Growth, Electricity Consumption, Time-Series Analysis*

Introduction

Energy is one of the main inputs to the production. Therefore energy is crucial for both developed countries and emerging and developing countries. The oil crises during the 1970s and the abnormal increases in oil prices in 1990s and 200s verified the importance of energy. So extensive studies have conducted on the interaction between economic growth and energy. Constantly increasing production in the world has increased the need of energy, but the scarcity of oil and natural gas resources in the world poses an obstacle for the sustainable economic growth.

Electricity power is a secondary energy resource obtained from the conversion of the primary energy resources such as fossil fuels (natural gas,

oil, coal) and wind energy. Coal has been the fuel mostly used in electricity generation, the share of nuclear power and natural gas in electricity consumption has increased in recent years, while the use of oil in electricity generation has declined since the late 1970s due to sharp increases in oil prices (IEA, 2013).World net electricity generation was 20.2 trillion kilowatt-hours in 2010 and expected to increase 39.0 trillion kilowatt-hours in 2040 by 93%. The growth of electricity demand in the OECD countries is slower than in the non-OECD countries (U.S. Energy Information Administration, 2013).

Emerging economies have experienced significant economic growth rates during the past decades. This study investigates the relationship between economic growth and electricity consumption in the increasingly emerging markets. The remainder of the study is organized as follows. Section 2 outlines the previous literature. Section 3 presents the data and methods; Section 4 presents empirical application and introduces the main findings. Section 5 concludes the study.

Literature review

There have been extensive studies on the relationship between energy consumption and economic growth in the literature. In these studies general energy consumption and electricity consumption were used. We focused on the literature which has examined the relationship between economic growth and electricity consumption, because we investigate the relationship between economic growth and electricity consumption in emerging countries. The literature review on the relationship between electricity consumption and economic growth was presented in Table 1. These studies generally used various co-integration and causality tests to investigate the relationship between electricity consumption and economic growth and they have reached different findings depending on the country/country group.

Most of the studies found that there was unidirectional causality between electricity consumption and economic growth, while Some studies such as Gurgul and Lach (2011), Bildirici and Kayıkcı (2012), Hu and Lin (2013), Ogundipe and Apata (2013) and Nazlioglu et al. (2014) found that there was bidirectional causality between electricity consumption and economic growth. The direction of unidirectional causality varies from

countries to countries. Some studies such as Shiu and Lam (2004), Altinay and Karagöl (2005) and Atif and Siddiqi (2010) have found that there was unidirectional causality from electricity consumption to economic growth, while some studies such as Ozun and Cifter (2007), Ciarreta and Zarraga (2007), Hye and Riaz (2008), Adom (2011) and Akinwale et al. (2013) have found that there was unidirectional causality from economic growth to electricity consumption. Relatively few studies such as Yu and Hwang (1984), Ciarreta and Zarraga (2007) and Aktaş and Yılmaz (2008) have reached there were no causality between electricity consumption and economic growth.

Table 1: Literature Review on the Relationship between Economic Growth and Electricity Consumption

Study	Country/Country Group (Period)	Method	Findings
Kraft and Kraft (1978)	United States (1947-1974)	Sims causality test	They found that there was unidirectional causality from GNP to gross energy input.
Yu and Hwang (1984)	United States (1947-1979)	Sims causality analysis	They found that there was no causality between GNP and electricity consumption.
Yu and Choi (1985)	5 countries (1950-1976)	Sims and Granger causality tests	They found that there was unidirectional causality from energy consumption to GNP in the Philippines and reverse causality from GNP to energy consumption in South Korea, while

Study	Country/Country Group (Period)	Method	Findings
			there was no causality in the United States, the United Kingdom and Poland.
Ferguson et al. (2000)	110 countries (1971-1995 and 1960-1995)	Correlation analysis	They found that rich countries had a strınger correlation between electricity consumption and economic growth than poor countries did and also there was stronger correlation between electricity consumption and economic growth than There is between total energy consumption and economic growth.
Shiu and Lam (2004)	China (1971-2000)	Johansen co-integration and Granger causality tests	They found that there was unidirectional causality from electricity consumption to economic growth.
Altinay and Karagöl (2005)	Turkey (1950-2000)	Dolado–Lütkepohl and Granger causality test	They found that there was unidirectional causality from electricity consumption to economic growth.
Ozun and	Turkey (1968-	Wavelet	They found that

Study	Country/Country Group (Period)	Method	Findings
Cifter (2007)	2002)	analysis	there was unidirectional causality from GNP to energy consumption in the long term.
Ciarreta and Zarraga (2007)	Spain (1971-2005)	Linear and nonlinear causality	They found that there was unidirectional linear causality from economic growth to electricity consumption with linear causality test, while there was no causality with nonlinear Granger causality test.
Karagöl et al. (2007)	Turkey (1974-2004)	ARDL bound test	They found that there was a positive relationship between economic growth and electricity consumption in the long run and there was a negative relationship between economic growth and electricity consumption in the short run.

Study	Country/Country Group (Period)	Method	Findings
Hye and Riaz (2008)	Pakistan (1971-2007)	ARDL bound testing approach and Granger causality	They found there was unidirectional causality from economic growth to energy consumption in the long term.
Aktaş and Yılmaz (2008)	Turkey (1970-2004)	Granger causality	They found there was unidirectional causality from economic growth to electricity consumption in the long term
Atif and Siddiqi (2010)	Pakistan (1971-2007)	Granger causality test and modified WALD test	They found that there was unidirectional causality from electricity consumption to economic growth.
Adom (2011)	Ghana (1971-2008)	Toda and Yamamoto Granger causality test	He found that there was unidirectional causality from economic growth to electricity consumption.
Gurgul and Lach (2011)	Poland (2000-2009)	Linear and nonlinear causality tests	They found that there was bidirectional causality between GDP and electricity consumption.
Bildirici and Kayıkcı (2012)	9European transition countries	Auto Regressive Distributed Lag analysis and Granger causality	They found that there was bidirectional causality between electricity consumption and

Study	Country/Country Group (Period)	Method	Findings
			economic growth in Belarus, Czech Republic, Hungary, Poland and Romania and unidirectional causality from economic growth to electricity consumption in Albania and unidirectional causality from electricity consumption to economic growth for Bulgaria and Slovakia in the long term.
Bildirici et al. (2012)	US, UK, Canada, Japan, China, India, Brazil, Italy, France, Turkey and South Africa (1978-2010)	ARDL analysis	They found that there was unidirectional causality from electricity consumption to real GDP in the US, China, Canada and Brazil, while there was unidirectional causality from economic growth to energy consumption in India, Turkey, South Africa, Japan, UK, France and Italy.

Study	Country/Country Group (Period)	Method	Findings
Yapraklı ve Yurttançıkmaz (2012)	Turkey (1970-2010)	Johansen co-integration and Granger causality test	They found that there was bidirectional causality between economic growth and electricity consumption.
Hu and Lin (2013)	Hainan Island (1988-2010)	Co-integration and Granger causality tests	They found that there was bidirectional causality between economic growth and electric power consumption.
Ogundipe and Apata (2013)	Nigeria (1980-2008)	Johansen and Juselius co-integration test and Granger causality test	They found that there was bidirectional causality between economic growth and electricity consumption.
Akinwale et al. (2013)	Nigeria (1970-2005)	Vector Auto Regressive (VAR) and Error Correction Model	They found that there was unidirectional causality from economic growth to electricity consumption.

Study	Country/Country Group (Period)	Method	Findings
Nazlioglu et al. (2014)	Turkey (1967-2007)	Bound testing co-integration, linear and nonlinear Granger causality tests	They found that there was a bidirectional between economic growth and electricity consumption with linear Granger causality test, while there was no causality between economic growth and electricity consumption with nonlinear Granger causality test.
Aslan (2014)	Turkey (1968-2008)	ARDL bound test and Granger causality test	He found that electricity consumption had a positive impact on economic growth and there was bidirectional causality between economic growth and electricity consumption.

Data and method

We used the annual data of electric power consumption (kWh) and GDP growth during the period 1991-2011 to investigate the relationship between economic growth and electricity power consumption. The data were taken from the World Development Indicators of World Bank. We took all the emerging economies (Brazil, Chile, China, Colombia, Czech Republic, Egypt, Greece, Hungary, India, Indonesia, Korea, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, Taiwan, Thailand, and Turkey) except Taiwan classified by Morgan Stanley Capital International. The

variables used in the econometric analysis and their symbols were presented in Table 2.

Table 2: Variables Used in the Econometric Analysis and Their Symbols

Variable Symbols	Variables
GDP	Real GDP Growth
EPC	Electric Power Consumption ((kWh))

We analyzed the long run relationship between economic growth and electric power consumption by Pedroni, Kao and Johansen Fisher co-integration tests and analyzed the existence and direction of causality between economic growth and electric power consumption by VAR Granger causality/Block exogeneity Wald causality test. Eviews 7.1, Stata 11.0 and Rats 8.1 statistical software packages were used in the analyses.

Econometric application and main findings

Stationarity analysis

The variables used in panel data analysis should be stationary as in all the time series analyses to avoid causing possible spurious relationships among the variables. Therefore we tested common unit root process by Levin, Lin ve Chu (2002) test and tested unit root process for every unit (country) by Im, Pesaran ve Shin (2003). The stationarity in the series independent from units by Augmented Dickey Fuller (ADF) (1979) test. The results of stationarity analyses of the data were presented in Table 3. We found that the time series were not stationary at the level [I(0)], therefore we took the first difference of the series and the series became stationary [I(1)]. So we used the first differences of the series in the analyses.

Table 3: Results of Panel Unit Root Test

	Levin,Lin&Chu Test Results		**Im,Pesaran&Shin** Test Results		ADF - Fisher Chi-square	
	Level	First Difference	Level	First Difference	Level	First Difference
Variables	Trend and Constant	Constant	Trend and Constant	Constant	Trend and Constant	Constant
GDP	0.092	0.0022*	0.0854	0.0001*	0.1132	0.0000*
EPC	0.068	0.0001*	0.0732	0.0017*	0.1084	0.0003*

The series were deseasonalized by tramo/seats during the stationarity analyses and periods of crisis and policy changes were considered. Trend and constant components were included in the model in selection of model as long as they were statistically significant.

* Significant at the 0.05 and 0.01 level; lags for ADF test are selected automatically by based on Schwarz information criterion.

Cusum path lies within the confidence interval bounds at %5, It is not observed structural breakpoint

Co-integration analysis

We used Pedroni, Kao and Johansen Fisher co-integration tests to determine whether there is a long run relationship between economic growth and electricity consumption. Pedroni (1999, 2000 and 2004) suggested some tests which allowed heterogeneity in the co-integration analyses. This test allows heterogeneity in co-integration vector (Asteriou and Hall, 2007:373). This test does not allow only dynamic and fixed effects to be different among the cross sections of panel, but also allows co-integrated vector to be different among the cross sections under alternative hypothesis (Güvenek and Alptekin, 2010, 181). Pedroni's approach becomes different from McCoskey and Kao (1998) approach in terms of assumption of cross sectional trend and null hypotheses which have nonexistence of co-integration. Allowing multiple regressors, varying of co-integration vector in different parts of panel and allowing heterogeneity of errors through cross sectional units constitute good sides of Pedroni's tests. Seven cointegration tests were presented to cover "within" and "between" effects in the panel and

these tests were separated as two different categories (Asteriou and Hall, 2007:374). The first category includes 4 tests which are pooled at "within" dimension; the second category includes the remaining 3 tests at "between" dimension. The first three of four tests in the first category are non-parametric tests. The first test is a statistic that is a kind of variance ratio. The second is similar to Phillips-Peron (PP) (rho) statistic and the third is similar to PP (t) statistic. The fourth statistic is a parametric statistic which is similar to Augmented Dickey Fuller (ADF) (t) statistic. The first one of three tests in the second category is similar to PP (rho) statistic; the other two tests are similar to PP (t) and ADF (t) statistics (Güvenek and Alptekin, 2010, 181). We used also Kao panel co-integration test, which was developed by Kao (1999) by using DF and ADF tests, and Johansen-Fisher panel co-integration test.

We determined the optimal lag length by using different criteria before the panel co-integration analysis. It was seen that different lag lengths were obtained depending on the criteria. Since error correction model for the AIC (Akaike Information Criterion), HQ (Hannan-Quinn Information) and SC (Schwarz Information Criterion) criteria were found to be consistent in the diagnostic tests and also many studies in the literature have determined the lag length depending on these criteria, we used the 3 lags in the analyses in the light of AIC, HQ and SC criteria.

The results of the co-integration tests were presented in Table 4. The test results demonstrated that there was a long run relationship between economic growth and electricity consumption except group rho and group ADF. We then applied FMOLS (Full Modified Ordinary Least Square) and DOLS (Dynamic Ordinary Least Square) to determine the coefficients of the long run relationship.

Table 4: Results of Co-integration Tests

	Results of Pedroni Panel Co-integration Test (Within-Dimension)			
	t statistic	Prob.	Weighted t statistic	Prob.
Panel v-Statistic	4.2231	0.0011*	4.6273	0.0004*
Panel rho-Statistic	-3.6678	0.0003*	-2.2445	0.0022*
Panel PP-Statistic	-3.2265	0.0000*	-2.7932	0.0004*
Panel ADF-Statistic	-3.8802	0.0000*	-2.5501	0.0011*

(Between-Dimension)		
	t Statistic	Prob.
Group rho-Statistic	-0.01157	0.1177
Group PP-Statistic	-2.94116	0.0021*
Group ADF- statistic	-0.45633	0.0778
Results of Kao Panel Co-integration Test		
	t- Statistic	Prob.
ADF	-2.86752	0.0013*
Residual variance	32235.98	
HAC variance	64532.18	

Results of Johansen Fisher Panel Co-integration Test				
Hypothesized No. of CE(s)	Fisher Stat. (from trace test)	Prob.	Fisher Stat. (from max-eigen test)	Prob.
None	345.21	0.0015	202.37	0.0034*
At most 1	97.34	0.0000	61.95	0.0000*

* Significant at the 0.01 and 0.05 level

Co-integration coefficient results of FMOLS and DOLS

We applied DOLS and FMOLS methods developed by Pedroni (2000) to estimate final unbiased coefficients of this relationship and test consistency of estimators with expectations following the co-integration tests. FMOLS method corrects the biases of estimators with standard fixed effects which are arisen from problems such as autocorrelation and heteroscedasticity, while DOLS is a method which can correct biases of static regression which are arisen from endogeneity problems by including dynamic considerations to the model (Kök et al., 2010:8). FMOLS method, which allows considerable heterogeneity among the individual cross sections, considers possible correlation between the differences of constant term, error term and independent variables.

FMOLS and DOLS estimation results were presented in Table 5. The panel FMOLS test results demonstrated that electricity consumption had positive impact on economic growth. 1% increase in electricity consumption led a 0.33% increase in economic growth. On the other hand the panel DOLS test results also demonstrated that electricity consumption had

positive impact on economic growth and 1% increase in electricity consumption led a 0.32% increase in economic growth. All the countries had statistically significant positive coefficient. Electricity had the largest impact on economic growth in Hungary, while it had the smallest impact in Indonesia.

Table 5: FMOLS and DOLS Estimation Results

Countries	FMOLS		DOLS	
	Coefficient	t stat.	Coefficient	t stat.
Panel	0.33	10.95	0.32	11.23
Brazil	0.42	12.31*	0.39	9.886*
Chile	0.31	9.652*	0.27	11.54*
China	0.25	11.76*	0.22	14.87*
Colombia	0.22	13.02*	0.24	12.50*
Czech Republic	0.36	17.42*	0.33	18.46*
Egypt	0.27	14.06*	0.25	13.04*
Greece	0.36	14.31*	0.38	15.87*
Hungary	0.54	15.93*	0.51	16.99*
Indonesia	0.19	21.42*	0.14	22.03*
India	0.25	29.27*	0.22	28.59*
Korea, Rep.	0.28	15.68*	0.31	10.68*
Mexico	0.31	11.99*	0.27	15.27*
Malaysia	0.29	12.54*	0.31	14.31*
Peru	0.38	11.52*	0.41	12.01*
Philippines	0.27	12.88*	0.29	13.45*
Poland	0.33	12.92*	0.35	12.86*
Russian Federation	0.47	13.46*	0.43	10.73*
Thailand	0.43	15.66*	0.41	12.64*
Turkey	0.39	14.79*	0.37	18.77*
South Africa	0.41	13.04*	0.44	12.03*

* Significant at the 0.01 and 0.05 level

Panel causality analysis

The long run relationship shows the existence of casual relationship among the variables, but it does not show the direction of causality. Therefore we tested the causality between economic growth and electricity consumption by Engle and Granger (1987) causality test. The results of Granger causality

test were presented in Table 6. We found that there was bidirectional causality between economic growth and electricity consumption.

Table 6: Results of VAR Granger Causality/Block Exogeneity Wald Tests

Dependent variable: GDP			
Excluded	Chi-sq	df	Prob.
EPC	15.12867	4	0.0044
All	15.12867	4	0.0044
Dependent variable: EPC			
Excluded	Chi-sq	df	Prob.
GDP	10.12578	4	0.0384
All	10.12578	4	0.0384

Conclusions

We examined the relationship between economic growth and electricity power consumption in emerging countries during the period 1970-2011 by using Pedroni, Kao and Johansen co-integration tests and Granger causality tests. The empirical findings demonstrated that that electricity consumption had a positive impact on the economic growth in the whole panel and electricity had the largest impact on economic growth in Hungary, while it had the smallest impact in Indonesia. The Granger causality test demonstrated that there was bidirectional causality between economic growth and electricity consumption. Our finding is consistent with Gurgul and Lach (2011), Bildirici and Kayıkcı (2012), Hu and Lin (2013), Ogundipe and Apata (2013) and Nazlioglu et al. (2014).

The bidirectional causality between economic growth and electricity consumption supported the feedback hypothesis for all the emerging countries, in other words economic growth and electricity consumption affects each other. This means that increases in economic growth raised electricity consumption and increasing electricity consumption increases economic growth. Therefore emerging countries should diversify energy supply and increase the share of renewable energy sources in energy consumption by considering their highly dependence on electricity.

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