A meta-analysis of the relationships between energy consumption and economic growth

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Abstract

This study employs meta-analysis, which has less been used before, to examine the causal relationship between energy consumption and economic growth. There are three research questions: (1) Is there an one-way relationship running from energy consumption to economic growth for most of developing countries (2) Is short run causality between the energy consumption and economic growth different from long run causality (3) Do the studies using the electricity consumption data alone yield different results from those using total energy consumption data. First, this study finds that the causality is not running from energy consumption to economic growth for most of developing countries; second, there exists different causalities from short run and long run. Last, the result demonstrates that the increase in electricity consumption directly affects economic growth and that economic growth also exerts farther electricity consumption. Further, policy implications are provided in the end.

關鍵詞：能源消耗、經濟成長、因果關係、後設分析

Key Words: Energy consumption, Economic growth, Granger causality, Meta-analysis.

1.Introduction

The causal relationship between energy consumption and economic growth is a well-studied topic in the energy economics literature. After suffering from the energy crisis from 1971 to 1980 and the post-energy crisis from 1981 to 2000, the price of energy hikes up which brought some issues on economic like energy saving policies or stimulates economic growth. As a result, since 1970s, the relationship between energy consumption and economic growth has undergone extensive investigation. The core concept has been whether energy consumption stimulates economic growth or economic growth spurs energy consumption. This has been the focus of debate in the last two decades. Supposing that the benefit in economic growth outweighs the cost of environmental damage, it is worth increasing energy use to accelerate economic growth. Oppositely, if energy consumption does not increase or even harmfully impacts economic growth, a conservation energy consumption policy is needed to avoid the harmful impacts on the economy. Many earlier analyses employed simple log-liner models estimated by ordinary least squares (OLS) without any regard for the nature of the time series properties of the variables involved. However, in the recent years, there are many accesses to survey the causal nexus between energy consumption and economic growth, including Granger causality (i.e., Sim's technique, Hsiao's technique, and Toda-Yamamoto test), co-integration, error correction model, and variance decompositions. Most of these studies used the Granger causality test, co-integration and error correction model to investigate the presence of short term or long-run equilibrium and the direction of the linkage between energy consumption and real GDP or economic growth. Though the topic of causal nexus between energy consumption and

economic growth has been well-studied in the energy economics literature, it seems like the findings are still controversial. From the first beginning, as a pioneer, Kraft and Kraft (1978) provide evidence to support unidirectional causality running from income (GNP) to energy consumption (EN) only in the case of the US over the period 1947-1974 by utilizing Sims (1972) methodology. There has been a proliferation of such studies using different techniques, time periods, distinct proxy variables, countries and different econometric methodologies since then. Using U.S. monthly data from 1973 to 1979, Akarca and Long (1979) showed instead that energy consumption leads employment (in the literature, some economists use employment or production to substitute for economic growth). However, these findings have been subjected to empirical challenge. Akarca and Long (1980), Erol and Yu (1987a), Yu and Choi (1985), and Yu and Hwang (1984) found no causal relationships between income (proxied by GNP) and energy consumption. Erol and Yu (1987b, 1989), Yu and Jin (1992), and Yu et al. (1988) went one step further to test the neutrality hypothesis and found a neutrality relation (i.e., no causal relationship between the two). By different means or countries, as you seen in the Table 1 and Table 2 which was formed separately by country-specific and multi-countries, the actual causalities are different from each others. These diverse outcomes might be owing to different countries' characteristics such as different indigenous supplies, different cultures and different political and economic histories. What's more, different energy policies will also contribute to extremely dissimilar consequences.

Ever since, studies based on different countries, methods, or periods also yielded mixed results. We can basically separate these empirical investigations into four segments. (1) No causality (GDP~EC): There is no causality between energy consumption and economic growth is called "neutrality hypothesis." (2) The uni-directional causality running from economic growth to energy consumption (GDP→EC). It is referred to as "conservation hypothesis." (3) The uni-directional causality running from energy consumption to economic growth (EC→GDP). It is called "growth hypothesis." (4) Between energy consumption and economic growth (EC↔GDP). This view implies that both energy consumption and economic growth Granger cause each other. It is also called "feedback hypothesis." It shows that energy consumption and economic growth affect each other at the same time. Such mixed prior results within a phenomenon that is seemingly straightforward warrant further study.

The direction of causation between energy consumption and economic growth has significant policy implication. For example, if it is found that unidirectional causality runs from energy consumption to economic growth, then conserving (or reducing) energy could reduce economic growth. On the other hand, if there exists unidirectional Granger causality running from economic growth to energy consumption, it may be implied that energy conservation policies may be implemented with little adverse or no effects on economic growth. The finding of no causality in either direction called 'neutrality hypothesis' (Yu and Jin, 1992), which means that neither conservative nor expansive policies in relation to energy consumption have any effect on economic growth.

The primary objective of this study is to synthesize the empirical research investigating the relationship between energy consumption and economic growth. In this study, we use Meta-analysis to examine the causal relationship between energy consumption and economic growth from three research questions: 1. Is there an one-way relationship running from energy consumption to economic growth for most of developing countries 2. Is short run causality between the energy consumption and economic growth different from long run causality 3. Do the studies using the electricity consumption data alone yield different results from those using total energy consumption data. The rest of the paper is organized as follows: Section 2 brings out some developments of research questions. Section 3 submits the method of meta-analysis. The main result will be presented in the section 4. We finish by the conclusion in the section 5.

2. Development of research question

2.1 developed versus developing countries

While surfing the literatures in the nexus between energy consumption and economic growth, countries are likely grouped into developed or developing (Asafu-Adjaye, 2000; Lee, 2005; Lee, 2006; Lee and Chang, 2007b). Most of literatures we display in the Table 1 and Table 2, the nexus between energy consumption and economic growth in developing countries have a tendency that energy consumption spurs the economic growth. In India, Masih and Masih (1996) found consistent evidence of energy consumption causing income through the error-correction term. Lately, by using the same method, Glasure and Lee (1997) tested the relationship between energy consumption and economic growth and presented a unidirectional causal relationship running from energy consumption to GDP in Singapore. Following, in the bi-variate model, Asafu-Adjaye (2000) added the price factor (using the consumer price index, i.e., CPI, to represent energy price) and applied Johansen's co-integration technique and the Granger causality test to investigate energy dependency and the relationship between energy consumption and economic growth. It shows a unidirectional causality with energy consumption leading economic growth in India and Indonesia. Subsequently, Oh and Lee (2004) shows the short run unidirectional causality running from energy to GDP. Moreover, Lee (2005) employed data on 18 developing countries from 1975 to 2001. This study uncovered causality running from energy consumption to income, and high energy consumption tends to have high economic growth, but not the reverse. Besides, in six developing countries, Iran, Pakistan, Indonesia, Malaysia, Singapore, and Tunisia, energy is regarded as an important input. Growth of energy has huge impact on growth rate GDP in all countries both in short- and long-run (Soytas and Sari, 2007). Further, as we know that no matter in the country-specific studies or multi-country studies, Granger causality and co-integration are used by authors constantly. According to these methods, in Turkey (Murray and Nan, 1996; Soytas et al., 2001; Soytas and Sari, 2003), in Taiwan (Lee and Chang, 2007a; Chiou-Wei et al., 2008), in Malaysia (Chiou-Wei et al., 2008), in Shanghai (Wolde-Rufael, 2004), and in Hong Kong (Ho and Siu, 2007) are support for the unidirectional causality. Therefore, we can bring out the research question:

Research Question 1: Is there an one-way relationship running from energy consumption to economic growth for most of developing countries?

2.2 short-run versus long-run

Looking back to the previous researches, using different econometric methodologies is one of segmentations which are sorted out from these studies. This is the reason why we are going to examine these studies by separating the group into short run and long run. With a view to arranging quantitative studies in the past time, short run and long run was chosen as a discuss group to looking forward a further result in this study. As a policy maker, making policies for short term or long term is an important decision. Though there exist studies which displayed the same direction both in the short-run and long-run like Hwang and Gum (1991). By using Co-integration and Error correction model to test the result, no matter in the short-run or long-run, we could find out the outcome is feedback hypothesis which means that energy consumption and GNP Granger causes each other in Taiwan. Then, we can conjecture that the government may set up some policies for one concept for feedback causality. However, on the other hand, it showed another consequence in the study which was pub lished by Lee and Chang (2005). The evidence showed that short-run and long-run causalities both run from energy consumption to GDP, but not vice versa. Moreover, there are still studies work on Commonwealth of Independent States and Central America which Apergis and Payne (2009b) examine the relationships between energy consumption and economic growth for eleven countries of the Commonwealth of Independent States

over the period 1991-2005. This study display the results of unidirectional causality from energy consumption to economic growth in the short-run while bidirectional causality between energy consumption and economic growth in the long-run. Further, a bi-directional causality between energy consumption and economic growth means that feedback hypothesis presence in the short run (Apergis and Payne, 2009c). Since the result plays an important role in energy policy no matter in short term or long term. Accordingly, here comes the research question:

Research Question 2: Is short run causality between the energy consumption and economic growth different from long run one?

2.3 Total energy consumption & Single electricity consumption

From the first of beginning, Kraft and Kraft (1978) find out a relationship that GDP Granger causes energy consumption; energy consumption seems like a substantial factor in the nexus. Since then, lots of energy items have been discussed extensively. Energy is classified with petroleum, coal, carbon, natural gas, CO_2, NO_x, and electricity consumption et al. By doing so, we hope that we are likely to having a deeper consequence. In the Table 3, we choose the literatures which electricity consumption was separated out as our samples. Yang (2000) use Granger's technique to re-examines the causality between energy consumption and GDP in Taiwan. This study presented a bi-directional nexus between electricity consumption and GDP growth in consequence. Following is the study in Turkey (Altinay and Karagol, 2005). With regard to the outcome, testing on the causal relationship between electricity consumption and real GDP has a strong evidence for unidirectional causality running from the electricity consumption to the income. This result indicates that the supply of electricity is extremely important to meet the growing electricity consumption. Thus, we can bring up that the causality runs from electricity consumption to economic growth in Turkey. Although public debates on electricity policy in Hong Kong focus on the regulation regime, Ho and Siu (2007) highlight the macroeconomic impact on it. Applying Error Correction Model and Co-integration, the study not only shows there is a long run equilibrium relationship between electricity consumption and real GDP, but a one-way causal effect exists from electricity consumption to real GDP. Further, a study which is published by Jamil and Ahmad (2010) analyzes the relationship among electricity consumption and real GDP. A supporting analysis in this study has correlated the electricity consumption and economic activity that the empirical result display unidirectional causality from real economic activity to electricity consumption. Then we can conclude that real GDP Granger causes electricity consumption. Whereas these literatures illustrate the nexus between electricity consumption and economic growth have a tendency to increase and the issue become more and more vital, we can have a discuss on the following research question:

Research Question 3: Do the studies using the electricity consumption data alone yield different results from those using total energy consumption data?

3. Method

Meta-analysis originated from agricultural research. It was founded and applied on the field of education and psychology by Glass in 1976 which portrayed that meta-analysis is kind of the statistical analysis in order to dealing with a large collection of results form different literatures. For the purpose of integrating these unlike findings, it is a quantitative method of synthesizing empirical evidences across a numerous studies which are relative. Meta-analysis has made tremendous progress in acceptance and impact in the last three decades as a distinct research method (Hunter & Schmidt, 2004). More, on account of including statistical analyses that detect effects or relationships that are unclear

in other approaches, meta-analysis offers advantages over conventional synthesis analyses such as historical accounts of research or descriptive synthesis of literature (Lipsey & Wilson, 2001). Even if there are lots of studies on medical researches and a large variety of marketing parameters have been meta-analyzed in the marketing literature, including research in advertising, consumer behavior, channels, research methods, there are less studies discuss on the nexus between energy consumption and economic growth. For the sake of solving this problem, in this study we utilize meta-analysis to investigate the relationship between energy consumption and economic growth. In the end, we are looking forward a clear outcome for the study. Below we describe how we manage our study.

3.1 Literature search

In this study, with a view to collecting relevant past studies, computer-based published empirical studies were conducted. The searches were conducted using the following key words: energy consumption, electricity consumption, economic growth, GDP, developed and developing countries. Manual searches were conducted of journal articles; references identified through the online database search. Manual searches of the *Energy, Energy Policy, Journal of Economics, Journal of Ecological Economics, Energy Economics, Journal of Applied Energy, Journal of Policy, and Resource and Energy Economics Modeling were also conducted.* Published studies conducted from 1996 to 2009, available in English. Further, the first part of research question, we defined our countries into developing and developed by the standard from the World Bank's World Development Indicators (2010).The literature search generated 63 manuscripts. Through the coding and recoding process, 33 manuscripts not meeting the eligibility criteria were not included in the study. As previously indicated, only studies for which an effect size can be computed were included in this meta-analysis.

3.2 Effect size

With an eye to having a consistent standard, we set out eligibility in our study. The study eligibility criteria serve three main purposes (Lipsey & Wilson, 2001). First, the characteristics of the criteria create a clear direction from which research studies are identified and examined. Second, the criteria offer a straightforward research sphere of energy consumption and economic growth. Finally, the criteria act as an essential guidance to the process of selecting or rejecting candidates for inclusion in the study. We use the primary data in order to find out the parameters between energy consumption and economic growth or electricity consumption and economic growth. In studies where the parameter between energy consumption and economic growth or electricity consumption and economic growth is not provided, we are not going to take it into our consideration. In this study, our sample is less than 30 by each group, and that is the reason why we are going to use T-Test Paired Samples Statistics to examine the data between energy consumption and economic growth or electricity consumption and economic growth. After we obtain the t-value, we will turn it into effect size (g).

$$g = t\sqrt{\frac{n1+n2}{n1n2}}$$

4. Results

In this study we investigate the nexus between energy consumption and economic growth. We probe the topic into three parts which were separated by developing versus developed, short- run versus long- run, and total energy consumption versus single electricity consumption. The literature search generated 63 manuscripts. Through the coding and recoding process, 33 manuscripts not meeting the eligibility criteria were not included in the study. As previously indicated, only studies for which an effect size can be computed were included in this meta-analysis. Recall that

eligibility was restricted to studies reporting a statistic between energy consumption and economic growth, such as F value, t value, P value, chi-square (x^2), Pearson's correlation coefficient (r), or coefficient of determination in linear regression (R^2). In this paper, we used Paired-Samples T Test to find out the t-value from three sections individually. Then, the second step aims to calculate the effect size.

4.1 Research Question 1: Is there an one-way relationship running from energy consumption to economic growth for most of developing countries?

When it comes to the first section, the t-value of developing and developed countries is separately equal to 1.394 (0.171)[18] and 1.586 (0.134). Following, we turn it into effect size become 0.4109 and 0.4657 which represents the developing and developed countries separately. While the result in this section that null hypothesis of a t-value test was rejected at the 10% significance level, and the effect size of developing countries is smaller than developed one, the research question about "Is there an one-way relationship running from energy consumption to economic growth for most of developing countries?" is not going to accept. According to the above, there comes out the result. First, we can find out that it is not always shows the unidirectional causality running from energy consumption to economic growth more apparent in developing countries than in developed countries. The causal relationship between energy consumption and economic growth may probably change by its own political situation, different time period, unlike methods or other factors. For example, in a developing country, Altinay and Karagol(2004) employing Hsiao's version of Granger causality method for the 1950-2000 period in Turkey. The main conclusion of this literature reveals that there is no evidence of causality between energy consumption and GDP in Turkey. Relatively, Erdal and Erdal(2008) apply the Johansen cointegration test, and Pair-wise Granger causality test to examine relation between energy consumption and GNP during the period 1970-2006 for Turkey. The empirical results indicate that the two series are found to be non-stationary. Although, the first differences of these series lead to stationary. By using the different access and the periods we chose, we could get distinct results from the same country.

4.2 Research Question 2: Is short run causality between the energy consumption and economic growth different from long run one?

As to the second part of the discussion, t-value of short run is 1.395 (0.188) and the other one of long run is 1.008 (0.337); the effect size of short run and long run is 0.5715 and 0.4129. Further, the null hypothesis of a t-value test was rejected at the 10% significance level. In the end of the test which means that it might display different consequences in the short run (on the Error Correction Model) and in the long run (Co-integration) of the causal relationship between the energy consumption and economic growth. Second, from the empirical results, when we investigate the causality between energy consumption and economic growth into a country, there could exhibit different outcomes from short-run and long-run in most of literatures. Besides, while we might find out different causalities in a country which was studied by Oh and Lee (2004), the case of Korea 1970-1999 apply a multivariate model of capital, labor, energy and GDP. The empirical results reveal a long run bidirectional causal relationship between energy consumption and GDP, and short run unidirectional causality running from energy to GDP. Moreover, upon using cointegration and vector error-correction modeling techniques to examines the dynamic causal relationships between pollutant emissions, energy consumption, and output for France (Ang, 2007), the causality results support that economic growth exerts a causal influence on growth of energy use and growth of pollution in the long run. The results also point to a unidirectional causality running from growth of energy use to output growth in the short run. As a result, a policy maker

1. The data in the parentheses is p-value. ** indicates significant at the 5% level.

should take not only short term, but also long term into consideration when they are trying to making a decision.

4.3 Research Question 3: Do the studies using the electricity consumption data alone yield different results from those using total energy consumption data?

Last, when we mention to the third research question, in this study, we choose electricity consumption as our single energy consumption and try to figure out the causality between electricity consumption and economic growth, especially to find out the difference while changing the viewpoint from total energy consumption into single electricity consumption. The empirical result of the t-value of total energy consumption and the electricity consumption are equal to 1.008 (0.337) and 1.052 (0.033) **. The effect size is 0.4873 and 0.5086, and the model was significant at 5% level. Consequently, the null hypothesis of the research question "Do the studies using the electricity consumption data alone yield different results from those using total energy consumption data?" cannot be rejected. However, in the last section of the research question, we can notice that electricity consumption holds a large percentage within total energy consumption. Just like we have mentioned before, these kinds of literatures illustrate the nexus between electricity consumption and economic growth have a tendency to increase and the issue become more and more vital, and we could obtain a result that the consumption of electricity is directly impact on the economic growth. Shiu and Lam (2004) examined the causal relationship between electricity consumption and real GDP for China. From the empirical result, Shiu and Lam (2004) pointed out that electricity consumption and real GDP for China are co-integrated and there exists unidirectional Granger causality running from electricity consumption to real GDP with no vice versa. In Turkey, Altinay and Karagol (2005) tested on the causal relationship between electricity consumption and real GDP has a strong evidence for unidirectional causality running from the electricity consumption to the income. This result indicates that the supply of electricity is extremely important to meet the growing electricity consumption. Moreover, public debates on electricity policy in Hong Kong, is focus on the regulation regime (Ho & Siu, 2007). In this literature, Ho and Siu (2007) found out the result which reports the finding that a one-way causal effect exists from electricity consumption to real GDP. Further, on the other hand, Yoo (2005) investigates the short- and long-run causality issues between electricity consumption and economic growth in Korea by using the co-integration and error-correction models. The overall results show that there subsists bi-directional causality between electricity consumption and economic growth. The meaning is that an increase in electricity consumption directly affects economic growth and that economic growth also exerts further electricity consumption. Consequently, how to promote the efficiency of the use of electricity or decrease the quantity will be an eventful issue to the government.

5. Conclusions

Most of the previous literatures used the Granger causality test, co-integration and error correction model to investigate the presence of short term or long-run equilibrium and the direction of the linkage between energy consumption and real GDP or economic growth. Though the topic of causal nexus between energy consumption and economic growth has been well-studied in the energy economics literature, it seems like the findings are still controversial. Since there is a growing literatures that inspect the causal relationship between energy consumption and economic growth, electricity consumption and economic growth, or other energy factors with economic growth, the purpose of this study is trying to figure out these controversial outcomes form plenty of previous literatures before, whether can we draw a conclusion to collect thoughts or not. Numbers of these literatures emphasize on developed, developing and emerging countries. What else, we can still separate the time period into short- and long- run or total

energy consumption and single electricity consumption. All of these segmentations are important for policymakers to understand the relationship between energy consumption or electricity consumption and economic growth in order to sketch effective energy and environmental policies. In this study, there are no unanimities neither on country-specific part nor time period section except for electricity consumption. In other words, after so many works on it, the outcomes from developing and developed countries or in the short- and long-run are still controversial. While some studies find causality running from energy consumption to economic growth, others obtain nexus running from economic growth to energy consumption and even some studies get no causality between these variables. These contradictory findings may rise up owing to the different data set, variables, econometric methodologies, or countries' characteristic. However, as we know that the causality between electricity consumption and economic growth demonstrates a "growth hypothesis", it seems like electricity consumption plays an important role in triggering off the economic growth. In nowadays, no matter in the emerging, developing, or developed countries, how to promote the efficiency of the usage of energy is the most important issue. Especially, as a result of the rapid growth of energy use worldwide, most of the developed countries are implementing building energy regulations such as energy standards, codes etc., to reduce building energy consumption. Further, the government should set out some honors and punishments to guide the residents to reduce the energy consumption; what else, trying to exploit more and more alternative energy or renewable energy. Like solar power energy, natural gas, terrestrial heat, and Biomass energy etc. In a word, a key feature of energy policy should be follow the conservation of energy which is concerned with the more efficient use of energy and a reduction in the amount of energy wasted. But the most important thing is to take all the situations into account within the country. Thanks to the results may change by the literatures we chose, so that we recommend that researchers should explore more and more literatures from diversity of database. Further, from previous study, Karanfil (2009) mentioned that it should be understand that research papers using the same methods with the same variables, just by changing the time period examined, have no more potential to make a contribution to the existing energy-growth literature. Authors should focus more on the new approaches. Therefore, for the future study, the researchers could extend and focus more on the research question, like a set of common variables, different intervals of time to derive more reliable and better results and comprehension about energy consumption and economic growth.

Table 1

Study survey of empirical studies on energy consumption and economic growth nexus

Authors (Year)	Period	Country	Methodology	Results
Stern (2000)	1948-1994	USA	Co-integration, Causality	EC→GDP
Soytas et al. (2001)	1960-1995	Turkey	Co-integration, Causality	EC→GDP
Glasure (2002)	1961-1990	Korea	Co-integration,ECM,variance decomposition	EC↔GDP
Hondroyiannis et al. (2002)	1960-1996	Greece	ECM	EC↔GDP
Altinay and Karagol (2004)	1950-2000	Turkey	Granger causality	GDP~EC
Ghali and El-Sakka (2004)	1961-1997	Canada	Co-integration, VEC, Causality	EC↔GDP
Paul and Bhattacharya (2004)	1950-1996	India	Co-integration, Causality	EC↔GDP
Oh and Lee (2004)	1970-1999	Korea	Granger causality and ECM	EC→GDP
Wolde-Rufael (2004)	1952-1999	Shanghai	Granger causality	EC→GDP
Lee and Chang (2005)	1954-2003	Taiwan	Johansen, Co-integration, VEC	EC→GDP
Ang (2007)	1960-2000	France	Co-integration, VECM	Energy use→GDP (in the short run)
Lee and Chang (2007a)	1955-2003	Taiwan	Causality, Co-integration, VECM	EC→GDP (only where there is a low level of energy consumption in Tai wan)
Jobert and Karanfil (2007)	1960-2003	Turkey	Granger causality	GDP~EC
Ho and Siu (2007)	1966-2002	Hong Kong	Co-integration, VECM	EC→GDP
Zamani (2007)	1967-2003	Iran	Co-integration, Causality, VECM	GDP→Total energy
Karanfil (2008)	1970-2005	Turkey	Co-integration, Causality	GDP→EC GDP~EC(when unrecorded economy is taken into account)
Ang (2008)	1971-1999	Malaysia	Co-integration, VECM	GDP→EC
Erdal et al. (2008)	1970-2006	Turkey	Causality, Co-integration	EC↔GDP
Bowden and Payne (2009)	1949-2006	USA	Causality	EC→GDP

Note: GDP→EC means that the causality runs from growth to energy consumption.

EC→GDP means that the causality runs from growth to energy consumption.

EC↔GDP means that bi-directional causality exists between energy consumption and growth.

GDP~EC means that no causality exists between energy consumption and growth.

VAR= vector autoregressive model, **VEC**= vector error correction model,

ARDL= autoregressive distributed lag, **ECM**= error correction model.

Table 2
Study survey of empirical studies on energy consumption and economic growth nexus for multi-country studies

Authors (Year)	Period	Country	Methodology	Results
Masih (1996)	1955-1990	6 Asian countries	Co-integration, ECM	EC→GDP (India) GDP→EC (Indonesia) EC↔GDP (Pakistan) GDP~EC (Malaysia, Philippines, Singapore)
Masih (1997)	1952-1992	Taiwan	Co-integration,	EC↔GDP
	1955-1991	Korea	VECM, variance	EC→GDP
Glasure and Lee (1997)	1961-1990	South Korea, Singapore	Co-integration, Causality	EC→GDP (Singapore) GDP~EC (South Korea)
Asafu-Adjaye (2000)	1971-1995	Philippine, Thailand	Co-integration,	EC→GDP (India, Indonesia)
	1973-1995	India, Indonesia	Causality	EC↔GDP (Philippine, Thailand)
Soytas and Sari (2003)	1950-1992	G-7 countries	Co-integration, Causality	EC→GDP (Turkey, France, Japan, Germany) GDP→EC (Italy, Korea) EC↔GDP (Argentina) GDP~EC (Brazil, India, Indonesia, Mexico, Poland, South Africa, US, UK, Canada)
Lee (2005)	1975-2001	18 developing countries	Panel VECM	EC→GDP
Wolde-Rufael (2005)	1971-2001	19 African countries	Granger causality	EC→GDP (Cameroon, Morocco, Nigeria) GDP→EC (Algeria, Congo DR, Egypt, Ghana, Ivory Coast) EC↔GDP (Gabon, Zambia) GDP~EC (Benin, Congo RP, Kenya, Senegal, South Africa, Sudan, Togo, Tunisia)
Lee (2006)	1960-2001	11 developed countries	Granger causality	EC→GDP (Belgium, Netherlands, Canada, Switzerland) GDP→EC (France, Italy, Japan) EC↔GDP (Sweden, USA) GDP~EC (Germany, UK)
Al-Iriani (2006)	1970-2002	6 countries of GCC (Bahrain, Kuwait, UAE Oman, Qatar, Saudi Arabia)	Panel co-integration, GMM	GDP→EC
Francis et al. (2007)	1971-2002	Haiti, Jamaica, Trinidad and Tobago	BVAR models, Co-integration	EC↔GDP (in short run for three countries) EC↔GDP (in long run for Trinidad and Tobago) GDP~EC (in long run, Haiti and Jamaica)
Mehrara (2007)	1971-2002	11 Oil Exporting countries (Iran, Kuwait, Saudi Arabia,	Panel co-integration	GDP→EC

		UAE, Oman, Bahrain, Mexico, Algeria, Nigeria, Ecuador Venezuela)		
Lee and Chang (2007b)	1965-2002 1971-2002	22 Developed countries, 18 Developing Countries	Panel VARs and GMM	GDP→EC (developing countries) EC↔GDP (developed countries)
Mahadevan and Asafu-Adjaye (2007)	1971-2002	20 energy importers and exporters	Panel error correction model	EC→GDP (in the short run for developing countries) EC↔GDP (developed countries)
Akinlo (2008)	1980-2003	11 countries	(ARDL) bounds	GDP→EC (Gambia, Ghana, Sudan, Zimbabwe, Congo, Senegal) GDP~EC (Cameroon, Cote d'lvoire, Nigeria, Kenya, Togo)
Chiou-Wei et al. (2008)	1954-2006	Asian countries and USA	Granger causality	EC→GDP (Taiwan, Hong Kong, Malaysia, Indonesia) GDP→EC (Philippines, Singapore) GDP~EC (USA, Thailand, South Korea)
Lee et al. (2008)	1960-2001	22 OECD countries	Panel co-integration, panel VECM	EC↔GDP
Huang et al. (2008)	1972-2002	82 Low-, middle- and high-income countries	Panel VAR, GMM model	GDP→EC (middle- and high-income countries) GDP~EC (low-income countries)
Narayan and Smyth (2008)	1972-2002	G-7 countries	Panel co-integration, Causality	EC→GDP
Lee and Chang (2008)	1971-2002	16 Asian countries	Panel co-integration and Panel ECM	EC→GDP (in the long run) GDP~EC (in the short run)
Apergis and Payne (2009a)	1980-2004	6 countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama)	Panel co-integration, ECM	EC→GDP
Apergis and Payne (2009b)	1991-2005	Armenia, Azerbaijan, Georgia, Kyrgyzstan, Kazakhstan, Belarus, Moldova, Russia, Tajikistan, Ukraine, Uzbekistan	Panel co-integration, ECM	EC→GDP (in the short run) EC↔GDP (in the long run)
Apergis and Payne (2009c)	1971-2004	Costa Rica, Guatemala, Nicaragua, Panama, El Salvador, Honduras	Panel vector error correction model	EC↔GDP (in the short run)

Note: GDP→EC means that the causality runs from growth to energy consumption.
EC→GDP means that the causality runs from growth to energy consumption.
EC↔GDP means that bi-directional causality exists between energy consumption and growth.
GDP~EC means that no causality exists between energy consumption and growth.

Table 3

Study survey on electricity consumption (ELC)- growth nexus

Authors (Year)	Period	Country	Methodology	Results
Yang (2000)	1954-1997	Taiwan	Granger causality	ELC↔GDP
Ghosh (2002)	1950-1997	India	Granger causality	GDP→ELC
Jumbe (2004)	1970-1999	Malawi	Granger causality, ECM	GDP→ELC (Granger causality) ELC↔GDP (ECM)
Morimoto and Hope (2004)	1960-1998	Sri Lanka	OLS regression, Causality	Electricity supply →GDP
Altinay and Karagol (2005)	1950-2000	Turkey	Causality	ELC→GDP
Yoo (2005)	1970-2002	Korea	ECM	ELC↔GDP
Narayan and Smyth (2005)	1966-1999	Australia	Multivariate Granger causality	GDP→ELC
Yoo and Kim (2006)	1971-2002	Indonesia	Engle Granger, VAR	GDP→ELC
Zachariadis and Pashouortidou (2007)	1960-2004	Cyprus	Causality,co-integration,VECM	ELC↔GDP
Mozumder and Marathe (2007)	1971-1999	Bangladesh	Co-integration and VECM	GDP→ELC
Ho and Siu (2007)	1966-2002	Hong Kong	Co-integration, VECM	ELC→GDP
Yuan et al. (2007)	19780-2004	China	Co-integration	ELC→GDP
Halicioglu (2007)	1968-2005	Turkey	Causality, Bounds testing	GDP→ELC
Tang (2008)	1972-2003	Malaysia	ECM, ARDL	ELC↔GDP
Hu and Lin (2008)	1982-2006	Taiwan	Co-integration, VECM	GDP→ELC
Yuan et al. (2008)	1963-2005	China	co-integration, VECM	ELC→GDP
Odhiambo (2009a)	1971-2006	Tanzania	ARDL Bounds testing	ELC→GDP
Abosedra et al. (2009)	1995-2005	Lebanon	Granger causality	ELC→GDP
Ghosh (2009)	1970-2006	India	ARDL bounds, co-integration, VECM	GDP→ electricity supply
Odhiambo (2009b)	1971-2006	South Africa	Granger causality	ELC↔GDP
Akinlo (2009)	1980-2006	Nigeria	Johansen-Juselius, co-integration, VECM	ELC→GDP

Note: GDP→ELC means that the causality runs from growth to electricity consumption.

ELC→GDP means that the causality runs from electricity consumption to growth.

ELC↔GDP means that bi-directional causality exists between electricity consumption and growth.

GDP~EC means that no causality exists between electricity consumption and growth.

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