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Energy consumption and economic growth—New evidence from meta analysis

Ping-Yu Chen [a], Sheng-Tung Chen [b], Chi-Chung Chen [c,*]

[a] Department of Applied Economics, National Chung-Hsing University, Taichung, Taiwan
[b] Department of Public Finance, Feng-Chia University, Taichung, Taiwan
[c] Department of Applied Economics, National Chung-Hsing University, #250 Kuo Kuang Rd., Taichung 40246, Taiwan

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ABSTRACT

The causal relationships between energy consumption and economic growth have given rise to much discussion but remain controversial. Alternative data sets based on different time spans, countries, energy policies and econometric approaches result in diverse outcomes. A meta analysis using a multinomial logit model with 174 samples governing the relationships between GDP and energy consumption is applied here to investigate the major factors that affect these controversial outcomes. The empirical results have demonstrated how the time spans, subject selections including GDP and energy consumption, econometric models, and tools for greenhouse gases emission reduction characteristics significantly affect these controversial outcomes.

1. Introduction

The relationship between GDP and energy consumption has given rise to considerable debate since the pioneering research of Kraft and Kraft (1978) who used annual data for the United States over the period 1947–1974 to explore the causal relationship between gross national product and energy consumption. Their research suggests that there is a uni-directional causal relationship from economic growth to energy consumption. However, in subsequent research, Akarca and Long (1980) used the same data set of Kraft and Kraft but changed the time periods of the sample and obtained a different result, which provided evidence that different sample intervals may change the empirical results on the issue of the relationship between gross domestic product (hereafter GDP) and energy consumption.

Estimation methodologies may also play an important role in this issue. Yu and Hwang (1984) adopted the E–G two-step method (Engle and Granger, 1987) using US quarterly data between 1974 and 1990, and found that there is no long-term cointegration equilibrium relationship between GDP and energy consumption. However, Stern (1993) applied a vector autoregressive model (VAR) to US data sets and found a uni-directional Granger causal relationship to exist from energy consumption to GDP if fuel composition consumption was replaced by energy consumption. Later, Stern (2000) used a single static cointegration analysis and multiple dynamic cointegration analysis to extend his previous research (Stern, 1993) and found energy consumption had a significant effect on GDP, which confirms that there is an obvious long-term equilibrium cointegration relationship between GDP and energy consumption. Furthermore, some literatures have provided more comprehensive evidences to support the relationship between energy consumption and economic growth through panel data set. For instance, Belke et al. (2011) found the bi-directional relationship between energy consumption and real GDP for 25 OECD countries from 1981 to 2007. The newly trivariate panel VECM model has also widely applied to examine the relationship between energy consumption and economic growth by Lee et al. (2008), Costantini and Martini (2010) and Lee and Lee (2010). Such evidences have shown that the improved or updated econometric models may change the findings of the relationship between energy consumption and GDP.

Such research has also proceeded in different countries including the U.K., Germany, Italy, France, Japan, and other industrial countries, while the major econometric models applied have included the standard Granger causality test model, the comprehensive error correction model, and the vector autoregressive model. For example, Hwang and Gum (1992), Asafu-Adjaye (2000) and Paul and Bhattacharya (2004) found that there exists a bi-directional relationship between the energy and economic variables, while Masih and Masih (1996, 1997) found that for Malaysia, Singapore and the Philippines a natural structural compliance relationship was found to exist between energy

* Corresponding author. Tel.: +886 4 2285 8137; fax: +886 4 2286 0255.
E-mail addresses: otarublue@hotmail.com (P.-Y. Chen), stonchen@fcu.edu.tw (S.-T. Chen), mayjune@nchu.edu.tw, mayjunejulychen@gmail.com (C.-C. Chen).

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consumption and income, India was found to exhibit uni-directional causality from energy consumption to GDP, Indonesia to exhibit a reverse causal relationship from GDP to energy consumption, and Pakistan and Taiwan to exhibit a bi-directional causal relationship between energy and GDP. Cheng and Lai (1997) also used a Granger causality test to test Taiwan's data over the period 1955–1993 and found evidence of only a uni-directional causal relationship from energy consumption to GDP. However, Asafu-Adjaye (2000) applied cointegration and error correction models to estimate the relationship between energy consumption and economic growth in India, Indonesia, Thailand, and the Philippines. The empirical results for the Philippines and Indonesia are different from those of Masih and Masih (1997). Furthermore, Yang (2000) updated the above sample interval to cover the period 1954–1997 and also obtained a controversial outcome.

Oh and Lee's (2004) research on South Korea found that there is no causal relationship between energy consumption and GDP in the short term, but that there is a uni-directional causal relationship from energy consumption to GDP in the long run. Lee (2005) analyzed the cointegration relationship between energy consumption and economic growth in 18 developing countries and the evidence showed that there is a long-run cointegration relationship from the perspective of the heterogeneous country effect. The results also indicated that there exist uni-directional causalities from energy consumption to GDP in both the short run and long run. Wolde-Rufael (2006) examined the long-term causal relationship between GDP per capita and electricity consumption per capita in 17 African countries over the period 1971–2001. The results indicated that there is long-term stable relationship between GDP per capita and energy consumption per capita in nine African countries, and that there is Granger causality between GDP per capita and energy consumption per capita in 12 African countries. Chen et al. (2007) conducted a similar study in 10 newly industrializing and developing Asian countries using both single data sets and panel data procedures. The empirical results based on single data sets indicated that the causality directions in the 10 Asian countries are mixed while there is a uni-directional short-run causality running from economic growth to electricity consumption and a bi-directional long-run causality between electricity consumption and economic growth if the panel data procedure is implemented.

The newly developing countries also get lots of attention to discuss the relationship between energy consumption and economic variables recently. For example, Wang et al. (2011) applied 28 provinces in China over the period 1995–2007 and found the bi-directional relationship between energy consumption and economic variables. Zhang (2011) and Sadorsky (in press) found the bi-directional relationship between energy consumption and economic variables in Russia and seven South America countries, respectively. And the bi-directional relationship is found by Eggoh et al. (2011) who estimated the relationship between energy consumption and economic growth for 21 African countries over the period from 1970 to 2006. Such relationship will be more diverse as developed countries are taken into consideration. For example, the research from Narayan and Smyth (2008) found the uni-directional causality from energy consumption to economic growth when G7 countries are considered. However, Belke et al. (2011) and Costantini and Martini (2010) found the bi-directional relationship between energy consumption and real GDP when OECD countries are applied. This indicates that the similar subject may come to different empirical results.

In this study, we refer the energy consumption to electricity consumption since electricity usage plays an essential role in the development of the global economy. Ferguson et al. (2000) examined the relationship between electricity consumption per capita and GDP per capita in more than 100 countries and found that the rich countries had more significant correlation between electricity usage and economic growth than poor countries. However, such relationships between electricity consumption and GDP have been found to be inconsistent among studies and depend on the economic development of a country, its energy usage, the econometric approach adopted, the time frame, and so on (Murray and Nan, 1994; Yang, 2000; Fatai et al., 2004; Shiu and Lam, 2004; Wolde-Rufael, 2004; Altinay and Karagol, 2005; Yoo, 2005; Chen et al., 2007; Ho and Siu, 2007; Narayan and Singh, 2007; Yuan et al., 2007, 2008; Hu and Lin, 2008; Narayan and Prasad, 2008; Akinlo, 2009).

Although the related conclusions of these studies on the relationships between energy and economic growth are still controversial, such outcomes could be briefly categorized into four types based on the studies by Ozturk (2010) and Payne (2010). In other words, the directions of the causal relationships between energy consumption and economic growth are listed as follows: no causality, uni-directional causality running from economic growth to energy consumption, uni-directional causality running from energy consumption to economic growth, and bi-directional causality between energy consumption and economic growth.

Although the controversial and inconsistent conclusions from the literature have not been resolved, the relationship between income and energy consumption may be described as one of these four types of relationships. We also observe that such alternative conclusions or these four types of relationships within the literature may be due to the subject/country selections, data time spans, empirical econometric model settings or other explanatory variable selections. Therefore, the main purpose of this study is to use the meta-analysis approach together with the multinomial logit model (hereafter MNL) to estimate the effects of potential factors on these controversial conclusions in regard to the issue of the relationship between energy consumption and economic growth. To this end, the 39 related studies with 174 samples that test the relationship between GDP and energy consumption will be examined while the multinomial logit model will be applied to investigate the factors impacting the relationships between GDP and energy consumption. The empirical results will show how such relationships are affected by these factors. In the sections that follow, the approach to data collection adopted in our research will be introduced in Section 2, and the detailed methodology of the MNL will be developed and illustrated in Section 3. The empirical results will be presented and discussed in Section 4 and the concluding remarks will appear in the Section 5.

2. Data

In this research, 174 data sets from 39 studies referred to in the literature related to the relationships between GDP and energy (electricity) consumption were compiled. The dependent variable selected consisted of the four types of relationship between energy consumption and economic growth referred to above, while the independent variables included GDP, Energy (Electricity) Consumption (hereafter EC), Economic Development Levels, Estimation Methods, and Carbon Tax in the relevant countries. The detailed data sets for these 39 studies are shown in Appendix A.

GDP data for each country were collected from the World Development Indicators database while EC data for each country were obtained from the Energy Information Administration's data on international energy consumption. The Economic Development variable showed whether the country observed was a