Energy Policy 39 (2011) 2121–2131

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Economic growth, energy conservation and emissions reduction: A comparative analysis based on panel data for 8 Asian-Pacific countries

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ARTICLE INFO

Article history:
Received 26 May 2010
Accepted 1 February 2011
Available online 23 February 2011

Keywords:
Energy consumption
Carbon emissions
Panel data model

ABSTRACT

This study was conducted to evaluate the causality between energy consumption, GDP growth and carbon emissions for eight Asia-Pacific countries from 1971 to 2005 using the panel data. The results indicate that there are long-run equilibrium relationships between these variables. Additionally, causality from energy consumption to CO_2 emissions was observed generally, but there were some opposite relationships also. Parameter estimations of the panel data model indicate that there are great differences in the carbon emissions, the efficiencies of energy use, carbon emissions of unit GDP and unit energy consumption between developed and developing countries. The base carbon emissions, per capita energy consumption and efficiency of energy use in developing countries are far lower than in developed countries; however, the CO_2 emissions per unit of energy use is higher. Although developing countries may reduce their CO_2 emission per unit energy use, total energy consumption will rise rapidly with economic development. Thus, developing countries must determine how to undergo economic growth while conserving energy and reducing emissions. To respond to global climate change, it is necessary to develop innovative technology for energy use, transform the energy structure and conduct the clean development mechanism.

1. Introduction

Global climate warming has become a serious threat to human survival and health. In addition to natural factors, global warming is closely related to CO_2 emissions produced by human activities (Soytas and Sari, 2009). Developing appropriate responses to climate change has become the most important environmental problem faced by the international community. The purpose of the Kyoto Protocol signed in 1997 was to restrict greenhouse gas (GHG) emissions in developed countries, and developing countries were asked to undertake the obligations of emission reduction at the Copenhagen Climate Conference in 2009. As a result, the causal relationships between energy consumption, economic growth and carbon emissions have become an international study topic in recent years. The question of whether developing countries should or should not be burdened with emissions reduction in international climate negotiations makes this issue an important aspect impacting international relationships.

Global climate change is largely caused by massive GHG emissions that have been produced by developed countries since the industrial revolution, and these countries have the capacity to prevent global warming as well. Based on these facts, it is reasonable for developing countries to require developed nations to reduce GHG emissions gradually based on their current emissions while allowing more carbon emissions by the developing nations. However, developed countries also want to be included in a new round of climate negotiations with developing nations. For China, the largest developing country, although its CO_2 emission per capita is only No. 73 worldwide, its total CO_2 emissions are the second highest in the world (Haakon et al., 2009). Thus, China faces the dilemma of development and emission reduction. Specifically, China requires a larger carbon emissions space to enhance its industrialization and urbanization, but it must also reduce its GHG emissions.

There are different causal links among the energy consumption, economic growth and carbon emissions at different stages of economic development in different countries (Dinda and Coondoo, 2006; Soytas and Sari, 2009; Huang et al., 2008). Comparing the trends in the efficiency of energy use and carbon emissions per unit GDP change between developed countries and developing countries, we can demonstrate the importance of technological progress in energy saving and carbon emissions, thereby enabling useful policy decisions. This will be of considerable importance for the coordination of national positions on climate change.

A review of previously conducted studies revealed that there were complex causal relationships between economic growth and

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doi:10.1016/j.enpol.2011.02.003

energy consumption. Specifically, short and long term unidirectional links from economic growth to energy consumption or the reverse and bi-directional relationships between variables were observed. Indeed, some studies have shown very different results when data from different groups of countries for the same period were analyzed using the panel Granger test. For example, Narayan and Smyth (2008) revealed long run causality between energy use and income in G-7 countries and found that causality appears to run both ways in four countries (Canada, Italy, Japan and UK), from energy use to income in two countries (US and France), and from income to energy consumption in Germany. Lee (2006) analyzed the causality between energy consumption and income in 11 major industrialized countries and discovered bi-directional causality in the United States, but unidirectional causality running from energy consumption to GDP in Canada, Belgium, the Netherlands and Switzerland. However, this relationship was the opposite in France, Italy and Japan. Moreover, a strong causality from economic growth to energy consumption was observed in 11 oil exporting countries (Mehrara, 2007), but energy consumption and income showed bi-directional causal linkages in 22 OECD countries (Lee et al., 2008). Finally, several studies of Asian countries revealed that energy consumption has a positive impact on economic growth (Lee et al., 2008; Fatai and Oxley, 2004; Wang and Liu, 2007), but there were opposite and bi-directional conclusions (Fatai and Oxley, 2004; Zhao, 2007; Oh and Lee, 2004).

In addition, some empirical studies failed to achieve unanimous conclusions, even if they were conducted in the same country within roughly the same period. For instance, the pioneering work conducted by Kraft and Kraft (1978) demonstrated the existence of Granger causality running from income to energy use for the United States using data covering the period of 1947–1974. However, Stern (1993) observed reverse causality using data for the period of 1947–1990. Moreover, Ang (2007) examined the dynamic causal relationships between two variables for France using panel a vector error correction model (VECM) and found that economic growth exerts a causal influence on energy use in the long run, and energy use points to output growth in the short run. Furthermore, the results obtained using panel data from many countries over various time periods also varied (Mahadevan and Asafu-Adjaye, 2007; Huang et al., 2008). However, a bi-directional relationship between economic growth and CO_2 emissions (Huang et al., 2008; Soytas et al., 2007), and a unidirectional causality running from energy consumption to carbon emissions (Dinda and Coondoo, 2006; Soytas et al., 2007; Halicioglu, 2009), has commonly been observed among studies (Table 1). There is a complex nexus between GDP-energy consumption and CO_2 emissions. The results obtained by Dinda and Coondoo (2006) suggest that there is more or less a bi-directional causal relationship between per capita GDP and per capita CO_2 emission for most countries. Accordingly, the movement of one variable directly affects the other variable through a feedback system. Furthermore, Pao and Tsai(2010) investigated CO_2 emission, energy consumption and economic growth in BRIC countries(Brazil, Russian, India and China); their results suggest that emissions strongly Granger-cause both energy consumption and output.

Some scholars have evaluated the links between type of energy and economic growth. Yuan et al. (2008) investigated the China case employing a VEC specification and found that Granger causality from electricity and oil consumption to GDP exists, but not from coal. Erol and Yu (1987) also found a unidirectional link from electricity consumption to income in Japan. Ciarreta and Zarraga (2010) investigated the relationship between electricity consumption and actual GDP for a set of 12 European countries and found evidence of a long-run equilibrium relationship between the three series and a negative short-run and strong causality from electricity consumption to GDP. Wolde-Rufael and Menyah (2010) evaluated the causal relationship between the nuclear energy consumption and the actual GDP for nine developed countries. They found a unidirectional causality running from nuclear energy consumption to economic growth in Japan, the Netherlands and Switzerland, the opposite unidirectional causality in Canada and Sweden and a bi-directional causality between economic growth and nuclear energy consumption in France, Spain, the United Kingdom and the United States.

Huang et al. (2008) reviewed many previously conducted studies and concluded that the differences in causal relationships obtained using data from the same country could be different due, in part, to differences in research periods or in research

Table 1
Summary of literature review.

Authors	Methods	Countries	Period	Results
Narayan and Smyth (2008)	Panel Granger test	G-7	1972–2002	EC→EG
Lee et al. (2008)	Panel VECM	16 Asia countries	1971–2002	EC→EG
Wang (2007)	Granger test	China	1978–2005	EC→EG
Stern (1993)	Granger test	USA	1947–1990	EC→EG
Zhao (2007)	Granger test	China	1953–2005	EC→EG
Ang (2007)	VECM	France	1960–2000	EC→EG
Halicioglu (2009)	ECM	Turkey	1960–2005	EC→EG
Mahadevan and Asafu-Adjaye (2007)	Panel VECM	Developing countries	1971–2002	EG→EC
		Developed countries	1971–2002	EC↔EG
Lee et al. (2008)	Panel Granger test	22 OECD countries	1960–2001	EC↔EG
Oh and Lee (2004)	VECM	South Korea	1970–1999	EG↔EC
Kraft and Kraft (1978)	Sims test	USA	1947–1974	EG→EC
Mehrara (2007)	Panel Granger test	11 oil exports countries	1971–2002	EG→EC
Fatai and Oxley (2004)	Granger causal test	New Zealand, Australia	1960–1999	EG→EC
Zhao (2007)	LSTR model	China	1953–2005	EG→EC
Ang (2007)	VECM	France	1960–2000	EG→EC
Huang et al. (2008)	Panel VAR model	82 countries	1972–2002	EG→EC
				EG→EC+(medial)
Soytas et al. (2007)	Granger causal test	USA	1960–2004	EC→CO_2
Halicioglu (2009)	ECM	Turkey	1960–2005	EC→CO_2
Dinda and Coondoo (2006)	ECM	88 countries	1960–1990	EG↔CO_2
Pao and Tsai (2010)	ECM	BRIC (4 countries)	1971–2005	EG↔CO_2
				CO_2→EG

Notes: →denotes leads, ↔denotes bi-directional causality or feedback, EC=energy consumption and EG=economic growth.