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Nuclear energy, renewable energy, CO_2 emissions, and economic growth for nine developed countries: Evidence from panel Granger causality tests

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ABSTRACT

The aim of this paper is to investigate the causal relationship between nuclear energy consumption, CO_2 emissions, renewable energy and real GDP per capita using dynamic panel for nine developed countries over the period 1990–2013. Capital and labor are included as additional variables. Results shown that there is a unidirectional causality running from renewable energy consumption to real GDP per capita for the whole panel at short run; this implies that policies for reducing energy consumption may not retard economic growth and income. However, there is no links between nuclear energy consumption and real GDP per capita, but a unidirectional causality from nuclear energy consumption to labor. Moreover, a bidirectional causality between labor and capital, and between CO_2 emissions and capital are found. In addition, there is a unidirectional causal relationship from labor to CO_2 emissions, while among other variables no causal relationship is found.

In the long run, there exists also a bidirectional causality between renewable energy consumption and real GDP per capita, which complain that renewable energy is a crucial component for economic growth. In addition, results revealed a unidirectional causality from GDP to CO_2 emissions.

1. Introduction

The nexus between nuclear energy consumption, CO_2 emissions and economic growth have been recently discussed in the economics literature. The overall results showed that there is a strong relationship between nuclear energy use and economic growth, between CO_2 emissions and economic growth, and between renewable energy consumption and economic growth. Nevertheless, there is a great concern about environmental challenge, since the energy consumption can causes economic growth but it is the key reason of environmental degradation. Yet, as current electricity production relies heavily on fossil fuels, it is expected that the expansion of production technologies based on nuclear energy and renewable energy would significantly reduce future emissions of greenhouse gases emissions (Hoffert et al., 2002; Service, 2005; Rohatgi et al., 2002).

Nuclear energy is considered as an alternative source to deal with high oil prices and to reduce dependence of foreign countries for energy requirement in some countries. Nuclear power stations are capital-intensive, and nuclear energy costs are less vulnerable to changes in fuel prices generation than coal or gas fired. Furthermore, nuclear energy is an important source in the development of energy and environmental strategies in long-term. Nuclear energy has meet global energy needs in some areas of the world where growth in energy demand is fast, oil and gas proved reserves are likely to be exhausted within a few generations, alternative resources are scarce, security of energy supply is a priority and reducing air pollution and emissions of greenhouse gases is essential (Fiore, 2006; Toth and Rogner, 2006). Responding to these difficulties, nuclear energy plays a key role in long-term development and environmental strategies. Nuclear energy meets to global energy needs worldwide with a growing energy demand. However, nuclear power growth are facing ongoing controversy, namely, operational safety, radioactive waste disposal, and the risk of proliferation of nuclear materials, as well as public perception and acceptance nuclear energy (Toth and Rogner, 2006).

In the context of their strategy to increase energy security, many countries have built nuclear power plants, not only to reduce

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dependence on oil imports and to extend secure energy supplies, but also to minimize price volatility associated with oil imports (Toth and Rogner, 2006 . Vaillancourt et al., 2008). In addition, the global interest in nuclear energy has become even more pressing since the Kyoto agreement, which requires signatories to have significantly reduced their CO_2 emissions and their effects on environment (Becker and Posner, 2005). Moreover, it is commonly recognized that free-carbon energy sources are the main solution to face global warming and to insure global energy security (Elliot, 2007; Ferguson, 2007).

The rest of this paper is organized as follows. The second section provides a literature review on the causal relationship between economic growth, nuclear energy consumption, CO_2 emissions and renewable energy consumption. Section 3 discusses the results and concluding remarks are given in Section 4.

2. Literature review

The causal relationship among nuclear energy consumption, CO_2 emissions and economic growth is the issue of various academic researches over the last few decades. Many papers have been appeared the last few years covering many geographic locations, using different econometric tools and including a range of control variables. Several studies have focused on a specific country while others have relied on a group of countries within a panel data framework. Economic growth measured in terms of gross domestic product (real or in per capita) or growth rate of GDP, using different econometric methodologies, countries and time period and have found conflicting results.

First group of researchers focused on the relationship between nuclear energy consumption and economic growth. The overall findings showed that there is a strong relationship between nuclear energy consumption and economic growth. Their results are synthesized into four testable hypotheses: feedback, growth, conservation and neutrality hypotheses. For an overview of previous studies, see Table 1. The growth hypothesis was investigated by Yoo and Jung (2005). They employ annual data covering the period 1977–2002 using error correction term. The results showed that there is a unidirectional causality running from nuclear energy consumption to economic growth in Korea without any feedback effect. The same study examined by Yoo and Jung (2005) to investigate the causality between nuclear energy consumption and economic growth in Korea by applying modems time-series techniques. The unidirectional causality running from economic growth to nuclear energy consumption without any feedback effects in France and Pakistan, and from nuclear energy to economic growth in Korea which supported the conservation hypotheses. Finally, the neutrality hypothesis was confirmed by Menyah and Wolde Rufael (2010) who studied the causal relationship between nuclear energy consumption and economic growth for nine industrialized countries. Their results showed the existence of neutrality hypothesis for the USA and France.

The second strand of researcher's emphases the causal relationship between nuclear energy consumption and CO_2 emissions. In this strand, Wolde-Rufael et al. (2010) studied the causal relationship between nuclear energy, CO_2 emissions and economic growth for a group of 19 developed countries and developing countries for the period 1984–2007 using the error correction model (ECM). The results from the panel Granger causality tests suggest that in the short-run nuclear energy consumption plays an important role in reducing of CO_2 emissions, but long-run estimation indicated that there is a statistically significant negative association between nuclear energy consumption and emissions. A recent study set by the nuclear energy agency support that is a key element in reducing GHG produced by fossil fuel sector.

Sadorsky (2009a) estimated an empirical model of renewable energy consumption for the G7 countries. Panel cointegration estimations showed that in the long term, increases in real GDP per capita and CO_2 per capita are found to be major drivers behind per capita renewable energy consumption. These results are robust across two different panel cointegration estimators. Oil price increases have a smaller although negative impact on renewable energy consumption. In this way, Yoo and Ku (2009) investigated the causal relationship between nuclear energy consumption and economic growth using a data from six countries among 20 countries that have used nuclear energy for more than 20 years until 2005. To this end, time-series techniques including the unit roots tests, co-integration, and Granger causality are employed to Argentina, France, Germany, Korea, Pakistan, and Switzerland. The main conclusion is that the causal relationship between nuclear energy consumption and economic growth is not uniform across countries. In the case of Switzerland, there exists a bidirectional causality between nuclear energy consumption and economic growth. This means that an increase in nuclear energy consumption directly affects economic growth and that economic growth also can stimulates further nuclear energy consumption.

In another study, Apergis and Payne (2010) examined the relationship between nuclear energy consumption and economic growth for sixteen countries within a multivariate panel framework over the period 1980–2005. Pedroni's (1999, 2004) used heterogeneous panel cointegration test, he noted that there is a long-run equilibrium relationship between real GDP, nuclear energy consumption, real gross fixed capital formation, and the labor force with the respective coefficients positive and statistically significant. The results of the panel vector error correction model showed a bidirectional causality between nuclear energy consumption and economic growth in the short-run while unidirectional causality from nuclear energy consumption to economic growth in the long-run. Thus, the results provide support for the feedback hypothesis associated with the relationship between nuclear energy consumption and economic growth. Similarly, Apergis et al. (2010) examined the causal relationship between CO_2 emissions, nuclear energy consumption, renewable energy consumption, and economic growth for a group of 19 developed and developing countries for the period 1984–2007 using a panel error correction model. The long-run estimation indicated that there is a statistically significant negative association between nuclear energy consumption and emissions, but a statistically significant positive relationship between emissions and renewable energy consumption. The results from the panel Granger causality tests suggest that in the short-run nuclear energy consumption plays an important role in reducing CO_2 emissions whereas renewable energy consumption does not contribute to reductions in emissions. This may be due to the lack of adequate storage technology to overcome intermittent supply problems as a result electricity producers which have to rely on emission generating energy sources to meet peak load demand.

Apergis and Payne (2010b) examined the causal relationship between renewable energy consumption and economic growth for 13 countries within Eurasia over the period 1992–2007 within a multivariate panel data framework. The heterogeneous panel cointegration test reveals a long-run equilibrium relationship exists between real GDP, renewable energy consumption, real gross fixed capital formation, and labor force. The results from the error correction models indicate a bidirectional causality between renewable energy consumption and economic growth in both short and long-run. Thus, the empirical findings lend support for the feedback hypothesis of the interdependent relationship between renewable energy consumption and economic growth. Menyah and Rufael (2010) explored the causal relationship between carbon