Energy Policy 39 (2011) 2111–2120

Contents lists available at ScienceDirect

Energy Policy

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

Oil prices, nuclear energy consumption, and economic growth: New evidence using a heterogeneous panel analysis

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ARTICLE INFO

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

Keywords:
Nuclear energy
Oil
Panel cointegration

ABSTRACT

This paper applies panel data analysis to examine the short-run dynamics and long-run equilibrium relationships among nuclear energy consumption, oil prices, oil consumption, and economic growth for developed countries covering the period 1971–2006. The panel cointegration results show that in the long run, oil prices have a positive impact on nuclear energy consumption, suggesting the existence of the substitution relationship between nuclear energy and oil. The long-run elasticity of nuclear energy with respect to real income is approximately 0.89, and real income has a greater impact on nuclear energy than do oil prices in the long run. Furthermore, the panel causality results find evidence of unidirectional causality running from oil prices and economic growth to nuclear energy consumption in the long run, while there is no causality between nuclear energy consumption and economic growth in the short run.

1. Introduction

Recently, many imported-energy-dependent countries in the world have experienced energy crises since the 1970s, a consequence of which oil prices increase rapidly and oil supply declines sharply, and have confronted global warming resulting from greenhouse gas (GHG) emissions. To combat these energy and environmental configurations, one of the important priorities of energy and environmental policies is to diversify the sources of energy and to find a secure, cheap and non-GHG-emitting energy supply (Fiore, 2006; Vaillancourt et al., 2008; Wolde-Rufael, 2010). As noted by the International Energy Agency (IEA, 2008), nuclear energy may answer these conditions. Nuclear energy provides a long-run and high-performance option, and may contribute to environmental policies for global climate control as well as to energy security (Apergis et al., 2010).[1] Besides, the development of nuclear energy can lead to the spill-over effect of industry-wide technology, and can promote the productivity of labor, capital and other factors of production (Frewer and Altvater, 1977; Yoo and Jung, 2005). Thus, in order to consider future economic development and energy demands, the development of nuclear energy is expected to be a valid option in the globally sustainable development strategy (Duffey, 2005; Omoto, 2005; Vaillancourt et al., 2008).

The importance of nuclear energy as providing a major solution to energy security and global warming directs us to investigate the determinants of nuclear energy consumption and the nuclear energy–economic growth nexus. Some researchers recently have examined the causal relationship between nuclear energy consumption and economic growth. However, except for Apergis and Payne (2010a) and Apergis et al. (2010), most of them adopt the time-series data of nuclear energy consumption for each individual country, which is insufficient, and thus their empirical results may suffer from small sample bias.

For the power of the traditional cointegration test (Johansen, 1988), multivariate systems with small sample sizes can be severely distorted. To this end, we need to combine information from time-series and cross-section data once again, and thus we use panel unit-root tests and heterogeneous panel cointegration tests, including heterogeneity in both the long-run relationships and the short-run dynamic adjustments.[2] The contributions and objectives of this paper are as follows.

First, this paper considers a multivariate model of nuclear energy consumption, real oil prices, oil consumption, and real income, which allows an additional channel of causality to be examined. In addition, we attempt to jointly analyze the energy-growth hypothesis and the effect of nexus between oil and nuclear energy.[3] To differ from the existing literature on the

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[1] Apergis et al. (2010) explored that nuclear energy consumption can significantly reduce CO_2 emissions, whereas the impact of renewable energy consumption on CO_2 emissions is insignificant.

[2] Kollias et al. (2008) employed a panel dataset of annual observations to overcome this cross-sectional data problem of underestimation. Furthermore, the use of panel data also allows us to control for both cross-section and time-period effects.

[3] Although our model is intuitively appealing, empirical work correctly involving the use of the variables in this area has several important gaps.

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doi:10.1016/j.enpol.2011.02.002

nuclear energy–income nexus that does not take oil consumption and real oil prices into account, we can estimate the cross-price elasticity of nuclear energy with respect to oil, and then analyze whether a substitute or complementary relationship between nuclear energy and oil exists.

Second, in this paper we test the long-run relationship among these variables employing the heterogeneous panel cointegration test developed by Pedroni (2004), which allows for cross-sectional interdependency among different individual effects. The elasticities of oil prices and real income for nuclear energy are estimated using the dynamic OLS (hereafter DOLS; Kao and Chiang, 2000) technique for heterogeneous cointegrated panels.

Third, since the causal relationship between nuclear energy consumption and economic growth and that between oil prices and nuclear energy consumption may run in either or both directions – whether or not being transitory or permanent – the estimations of the vector error-correction model (VECM) which we use to test the statistical causality hypothesis are more reliable than those from a single equation model. We also apply a panel VECM to distinguish between short-run and long-run causalities.

Fourth and finally, it is well-known that erroneously omitted breaks can cause a deceptive inference in time-series testing and the effects of structural breaks do not disappear simply because one uses panel data. The current research makes a valuable contribution to this line of research stemming from the fact that the phenomenon of structural breaks is a common problem in macroeconomic series, given that they are usually affected by exogenous shocks in environmental or economic events (Altinay and Karagol, 2004; Rao and Kumar, 2009). The direction, strength, and stability of the relationship among nuclear energy, oil market activities, and real income play a pivotal role in the implementation of energy or environmental policies.

The remainder of this study is organized as follows. Section 2 provides the brief literature review. Section 3 introduces the panel unit-root tests, panel cointegration techniques and the causality tests. Section 4 illustrates the definitions for the variables, data sources and provides the empirical result. A conclusion is provided in Section 5.

2. Literature review

Ever since the seminal contribution of Kraft and Kraft (1978) who found unidirectional causality from income to energy consumption in the U.S., much of the literature has investigated the short- and long-run relationships between energy consumption and economic growth in the recent three decades. Evidence of causality between energy consumption and economic growth in either direction may have significant bearings upon policy. For example, the finding of unidirectional causality running from energy consumption to economic growth indicates an energy-dependent economy in which energy is an impetus to economic growth. It implies that the shortage of energy may have a negative impact on economic growth, and thus energy conservation policies would harm economic growth (Masih and Masih, 1997). However, unidirectional causality also runs from economic growth to energy consumption, indicating a less energy-dependent economy. It implies that energy conservation policies may have few or adverse effects on economic growth (Jumbe, 2004). Furthermore, the finding of no causality in either direction, which is the so-called 'neutrality hypothesis', would imply that energy consumption does not affect economic growth, and as such, energy conservation policies may be pursued without adversely affecting economic growth (Yu and Choi, 1985). In contrast, bidirectional causality indicates that energy consumption can enhance economic growth and economic growth in turn may lead to an increase in the demand for energy (Lee, 2006), implying that energy consumption and economic growth are interdependent and that energy conservation policy may negatively affect economic growth.

However, energy consumption variables utilized by the existing literature are generally total energy consumption or electricity consumption,[4] while a few studies have investigated the casual relationship between nuclear energy consumption and economic growth (see Table A1 of Appendix A). Yoo and Jung (2005) analyzed the short-run and long-run causalities between nuclear energy consumption and economic growth in Korea. They found evidence of unidirectional causality running from nuclear energy consumption to economic growth in Korea without any feedback effect. Yoo and Ku (2009) utilized time-series data of 20 countries to investigate the nuclear energy consumption–economic growth nexus, but they employed the causality test for six countries since only these countries' data is integrated of order one (I(1)). Their empirical results demonstrate that unidirectional causality runs from nuclear energy consumption to economic growth in Korea, while unidirectional causality runs from economic growth to nuclear energy consumption in France and Pakistan. Evidence of bidirectional causality between nuclear energy consumption and economic growth exists in Switzerland, and the absence of no causality between them is found in Argentina and Germany. For India, Heo et al. (in press) found unidirectional causality running from nuclear energy consumption to economic growth in both short- and long-run relationships.

One thing worth noting is that a bivariate framework used by the above three studies may not consider the potential impact of other variables on the nuclear energy–economic growth nexus. Loizides and Vamvoukas (2005) indicated that the introduction of a third or fourth variable in the causality test may change the direction of causality. Furthermore, since a four-variable framework has more information than a bivariate framework, the causal results may be more reliable. Thus, the remaining studies analyzed the causality between nuclear energy consumption and economic growth by using a multivariate framework with labor and capital (Apergis and Payne, 2010a; Wolde-Rufael, 2010; Wolde-Rufael and Menyah, 2010; Payne and Taylor, 2010; Wolde-Rufael, in press), with CO_2 emissions and renewable energy consumption (Menyah and Wolde-Rufael, 2010; Apergis et al., 2010). Using the Toda and Yamamoto (1995) version of the Granger non-causality test, the absence of causality between nuclear energy consumption and economic growth can be found in the U.S. (Menyah and Wolde-Rufael, 2010; Payne and Taylor, 2010) and in Taiwan (Wolde-Rufael, 2010).

Wolde-Rufael (2010) has indicated evidence of unidirectional causality running from nuclear energy consumption to economic growth. For nine developed countries, Wolde-Rufael and Menyah (2010) examined the causal relationship between nuclear energy consumption and real GDP. They found unidirectional causality running from nuclear energy consumption to economic growth in Japan, the Netherlands and Switzerland, with reserve causality running from economic growth to nuclear energy consumption in Canada and Sweden. In addition, there was bidirectional causality between nuclear energy consumption and economic growth in France, Spain, the U.K. and the U.S.A. Using panel data of 16 countries, Apergis and Payne (2010a) found evidence of bidirectional causality between nuclear energy consumption and economic growth in the short run, with unidirectional causality running from nuclear energy consumption to economic growth

[4] Payne (2010a, 2010b) provided a nice survey of the energy consumption–economic growth and electricity consumption–economic growth literature.