Energy Economics 33 (2011) 236–248

Contents lists available at ScienceDirect

Energy Economics

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

Nuclear energy consumption, oil prices, and economic growth: Evidence from highly industrialized countries

Chien-Chiang Lee *, Yi-Bin Chiu

Department of Finance, National Sun Yat-sen University, Kaohsiung, Taiwan

ARTICLE INFO

Article history:
Received 18 February 2010
Received in revised form 16 May 2010
Accepted 1 July 2010
Available online 24 July 2010

JEL classification:
Q40
Q43

Keywords:
Nuclear energy consumption
Oil prices
Economic growth
Granger causality test

ABSTRACT

This study utilizes the Johansen cointegration technique, the Granger non-causality test of Toda and Yamamoto (1995), the generalized impulse response function, and the generalized forecast error variance decomposition to examine the dynamic interrelationship among nuclear energy consumption, real oil price, oil consumption, and real income in six highly industrialized countries for the period 1965–2008. Our empirical results indicate that the relationships between nuclear energy consumption and oil are as substitutes in the U.S. and Canada, while they are complementary in France, Japan, and the U.K. Second, the long-run income elasticity of nuclear energy is larger than one, indicating that nuclear energy is a luxury good. Third, the results of the Granger causality test find evidence of unidirectional causality running from real income to nuclear energy consumption in Japan. A bidirectional relationship appears in Canada, Germany and the U.K., while no causality exists in France and the U.S. We also find evidence of causality running from real oil price to nuclear energy consumption, except for the U.S., and causality running from oil consumption to nuclear energy consumption in Canada, Japan, and the U.K., suggesting that changes in price and consumption of oil influence nuclear energy consumption. Finally, the results observe transitory initial impacts of innovations in real income and oil consumption on nuclear energy consumption. In the long run the impact of real oil price is relatively larger compared with that of real income on nuclear energy consumption in Canada, Germany, Japan, and the U.S.

1. Introduction

During the two energy crises in the 1970s, the price of oil doubled, even tripled in some countries, resulting in an increase of production cost and sharply reducing export competitiveness, which may have reduced imported-energy-dependent countries' economy performance and international competitiveness. Fossil fuels including coal, oil, and gas nowadays provide 85% of energy needs, and fossil-fuelled economic growth is the main factor for global warming through the release of carbon dioxide (CO_2) into the atmosphere. In December 1997 the third session of the Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto, Japan adopted the Kyoto Protocol. Annex I countries agreed to reduce their collective greenhouse gas emissions by 5.2% from their 1990 level by 2008 to 2012. The U.S. President Obama's New Energy for America plans to reduce 10 million barrels of oil consumption per day by 2030 and to cut the country's collective greenhouse gas emissions by 80% from the 1990 level by 2050.

To combat these energy and environmental configurations, one of the important priorities of energy and environmental policy 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, as it reduces the instability of oil prices, the dependence on oil imports for many countries, and greenhouse gas emissions. Therefore, nuclear energy (non-carbon energy) may be a crucial substitute energy for oil, and whether imported-energy-dependent countries can adopt nuclear energy to replace the majority of fossil fuels in their economy has become an important issue.

Based on the factors above, this study employs extensive tests from a multivariate model to investigate the relationship among nuclear energy consumption, oil price, oil consumption, and real income. We extend the existing energy consumption literature to nuclear energy. Furthermore, this study examines if there is the same pattern to countries that are highly industrialized and have a similar level of economic development, and goes on to investigate if these countries have different impacts from oil price fluctuations on nuclear energy consumption.

While the drivers behind different types of energy consumption (i.e. electricity, oil, coal, etc.) have been well studied, relatively little is known about the drivers behind nuclear energy consumption (i.e. Schurr, 1983; Yoo and Jung, 2005; Yoo and Ku, 2009; Apergis and Payne, 2010; Menyah and Wolde-Rufael, 2010; Wolde-Rufael, 2010;

* Corresponding author. Tel.: +886 7 5252000x4825; fax: +886 7 5254899.
E-mail address: cclee@cm.nsysu.edu.tw (C.-C. Lee).

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doi:10.1016/j.eneco.2010.07.001

Wolde-Rufael and Menyah, 2010; Heo et al., in press; Payne and Taylor, in press; Wolde-Rufael, in press). Nonetheless, the existing empirical studies on the nuclear energy-income nexus suggest conflicting conclusions. One problem may be that most of them suffer from the omission variable bias. The bivariate models with energy consumption and real income may be biased and "unfortunately blurry" due to the omission of other variables such as another substitute energy.

To improve the problem of the omission variable bias and based on the production function, Apergis and Payne (2010), Wolde-Rufael (2010), Wolde-Rufael and Menyah (2010), Payne and Taylor (in press), and Wolde-Rufael (in press) incorporate capital and labor inputs to examine the causal relationship between nuclear energy consumption and economic growth. However, none of the existing studies on nuclear energy investigate the impacts from oil price and oil consumption changes on nuclear energy development under international crude oil price hikes and oil supply shortages.

The purposes and contributions of this study are as follows. First, we control for real oil price and oil consumption, 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.[1] Second, this study is the first one utilizing a model with nuclear energy consumption as a dependent variable to examine the income elasticity of nuclear energy consumption and to analyze the impact of the policy for stimulating economic growth on nuclear energy development. Third, most studies on nuclear energy consumption focus on the causal relationship between nuclear energy consumption and real income, and thus they cannot find a dynamic relationship between them.[2] To fill this gap, we employ the generalized impulse response function (GIRF) and the generalized forecast error variance decompositions (GVDC) to explore the dynamic relationship among nuclear energy consumption, real oil price, oil consumption, and real income. Fourth, this study applies the samples of six highly industrialized countries (G-6 countries), which play a critical role in the global economy, and thus our motivation appears meaningful. The estimated results for these highly industrialized countries provide the direction for the future nuclear energy progress of the developing countries.

The remainder of the study is organized as follows. Section 2 reviews previous research in the empirical literature. Section 3 introduces the Toda and Yamamoto (1995, TY) Granger non-causality test, and the GIRF and GVDC of Koop et al. (1996) and Pesaran and Shin (1998). Section 4 shows the variables' definitions, data sources, and the empirical results. Section 5 offers the conclusion.

2. Literature review

Ever since the seminal contribution of Kraft and Kraft (1978), a plethora of literature investigates the short- and long-run causal relationships between energy consumption and economic growth in the past three decades. However, the energy consumption variables utilized by existing literature are total energy consumption or electricity consumption (Wolde-Rufael, 2006; Lee and Lee, 2010; Payne, 2010a, 2010b),[3] yet relatively few studies touch upon the casual relationship between nuclear energy consumption and economic growth. All existing studies ignore the interaction among nuclear energy consumption, oil price, oil consumption, and real income.

Schurr (1983) finds evidence of a positive relationship between stocks of nuclear energy and economic growth. Utilizing Johansen's cointegration technique, the error-correction model (ECM), and the Granger causality test, Yoo and Jung (2005) analyze the nuclear energy consumption-economic growth nexus for South Korean yearly data spanning from 1977 to 2002. They present that nuclear energy consumption influences economic growth, but economic growth does not influence nuclear energy consumption. Yoo and Ku (2009) investigate the relationship between nuclear energy consumption and economic growth for 20 countries and indicate that for only 6 countries, i.e. Argentina, France, Germany, South Korea, Pakistan, and Switzerland, the data are integrated of degree one (i.e. I(1)). Thus, they only carry out short- and long-run causality tests for these 6 countries, but not for the other 14 countries. Their empirical results show evidence of unidirectional causality running from nuclear energy consumption to economic growth in South Korea, whereas unidirectional causality runs from economic growth to nuclear energy consumption in France and Pakistan. In Switzerland, there is a bidirectional causal relationship between nuclear energy consumption and economic growth, but no causal relationship between them in Argentina and Germany. Heo et al. (in press) show that there is unidirectional causality running from nuclear energy consumption to economic growth without any feedback effect. Using panel data of 16 countries, Apergis and Payne (2010) find 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 in the long run.

Due to the different integrated orders of each variable and the biased results of the unit root, the conventional causality test may be not carried out and may obtain incorrect results. To eliminate the need for potentially biased pre-tests for unit roots and cointegration, Menyah and Wolde-Rufael (2010), Wolde-Rufael (2010), Wolde-Rufael and Menyah (2010), Payne and Taylor (in press), and Wolde-Rufael (in press) apply the TY (1995) Granger non-causality test, which is valid regardless of whether the variables are I(0) or I(1) as well as non-cointegrated or cointegrated. For the U.S., Menyah and Wolde-Rufael (2010) examine the causal relationship between CO_2 emissions, renewable and nuclear energy consumption, and real GDP. They find no causality between nuclear energy consumption and real GDP. Using capital and labor inputs as additional variables, Wolde-Rufael (2010) shows evidence of significantly positive unidirectional causality running from nuclear energy consumption to economic growth without any feedback for India. Wolde-Rufael and Menyah (2010) indicate evidence of unidirectional causality running from nuclear energy consumption to economic growth in Japan, the Netherlands, and Switzerland, whereas unidirectional causality runs from economic growth to nuclear energy consumption in Canada and Sweden. In addition, there is a bidirectional causality between nuclear energy consumption and economic growth in France, Spain, the U.K. and the U.S. Furthermore, Payne and Taylor (in press) and Wolde-Rufael (in press) find an absence of causality between nuclear energy consumption and economic growth, respectively, in the U.S. and Taiwan, supporting the neutrality hypothesis.

One thing worth noting is that if we only focus on the bivariate model for the relationship between nuclear energy consumption and economic growth, then the empirical results may suffer from the omission variable bias (Lütkepohl, 1982). Loizides and Vamvoukas (2005) argue that the introduction of a third or a fourth variable in the causality test may change the direction of causality. Thus, to improve the omission variable bias, some studies have analyzed the causality between nuclear energy consumption and economic growth by using a multivariate framework with labor and capital inputs (Apergis and Payne, 2010; Wolde-Rufael, 2010; Wolde-Rufael and Menyah, 2010; Payne and Taylor, in press; Wolde-Rufael, in press) or with CO_2 emissions and renewable energy consumption (Menyah and Wolde-Rufael, 2010). Except for Menyah and Wolde-Rufael (2010), they do

[1] If it has a substitute effect, then countries could replace oil with nuclear energy under an upsurge in international crude oil prices. If it has a complementary effect, then countries may not reduce oil demand by developing nuclear energy.

[2] Granger causality tests are sensitive to omitted variables bias. Hence, that is one of the reasons why we employ a multivariate framework instead of a bivariate one to begin with.

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