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Oil Market, Nuclear Energy Consumption and Economic Growth: Evidence from Emerging Economies

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ABSTRACT: This paper empirically examines the relationship between oil consumption, nuclear energy consumption, oil price and economic growth in four emerging economies (Russia, China, South Korea, and India) over the period from 1965 to 2010. Applying a modified version of the granger causality test developed by Toda and Yamamoto, we find that the level of world crude oil prices (WTI) plays a crucial role in determining the economic growth in the investigated countries. The results suggest that there is a unidirectional causality running from real GDP to oil consumption in China and South Korea, while bidirectional relationship between oil consumption and real GDP growth appears in India. Furthermore, the results propose that while nuclear energy stimulates economic growth in both South Korea and India, the rapid increase in China economic growth requires additional usage of nuclear energy.

Keywords: nuclear energy consumption; oil consumption; economic growth; oil prices; Granger causality test
JEL Classifications: Q40; Q43; Q48

1. Introduction

Over the past several decades, a plethora of empirical studies have devoted increasing interest to investigating the relationship between energy consumption and economic growth in both developing and developed countries. The importance of energy consumption in economic development process has triggered interest in empirically identifying the nature of casual linkage, which has important implications to develop sound energy policies. Apergis and Payne (2010) provide an enlightening account on the relationship between energy and GDP growth and how policy, depending on its aims and objectives, may respond to four major hypotheses. First, under the growth hypothesis, energy saving policies which reduce energy consumption may have an adverse impact on real GDP, because the economy is very dependent on energy to grow Masih and Masih (1997). Accordingly, negative energy shocks and energy conservation policies me depress economic growth. Second, the conservation hypothesis advocates for an implementation of conservation energy policy, as the economic growth would not be slowed down. Third, the neutrality hypothesis suggests that energy consumption has a little or no impact on GDP; therefore, energy conservation policies do not effect economic growth Asafu-Adjaye (2000). Forth, the feedback hypothesis confirms the independence between energy consumption and economic growth and they are complements to each other. This encourages the implementation of energy expansionary policies for a long run sustainable economic growth.

Empirically, numerous studies in the energy economics literature have investigated the relationship between the use of energy/electricity and macroeconomic performance for developed and developing countries. Their findings are inconclusive, however. For example, some studies, such as Glasure (2002), Narayan and Prasad (2008), Narayan and Prasad (2008), and Kaplan et al. (2011) have found bidirectional Granger causality between energy consumption and real GDP. Some others, such as Nachane et al. (1988), Stern (1993), Lee and Chang (2005), and Bowden and Payne (2009), have found a uni-directional Granger causality running from energy consumption to real GDP. By contrast, Kraft and Kraft (1978), Yu and Choi (1985), Soytas and Sari (2003), Erol and Yu (1987), Masih and

Masih (1996), Lee (2006), Binh (2011), Zachariadis (2007), Ozturk et al. (2013 have documented evidence of the unidirectional Granger causality running from real GDP to energy consumption. On the other hand, several empirical studies including Murry and Nan (1994), Altinay and Karagol (2004), Chontanawat et al. (2006), Jobert and Karanfil (2007), Karanfil (2008) have concluded that there exists no causal relation between energy consumption and GDP, conforming the neutrality of energy. Others such as Farhani and Ben Rejeb (2012) and Lau et al. (2011) find that the results may evern differ on the basis of testing short or long-run relationships. Lau et al. (2011) have investigated the energy-growth causality for seventeen selected Asian countries and indicate that energy is a force for economic growth in the short-run, but in the long-run, the energy consumption is fundamentally driven by economic growth. A detailed energy-growth nexus literature survey can be found in the paper of Ozturk (2010).

The lack of uniformity in the results in literature, among other things, may arise due to different data set, countries characteristics, variables used and different econometric methodologies employed (Ozturk, 2010; Menegaki, 2014). The findings from studies vary not only across countries, but depend also on methodologies within the same country (Soytas and Sari (2003)). Meanwhile, energy consumption variables that are utilized in existing literature are generally total energy consumption or electricity consumption as proposed by Alvarez-Ramirez et al. (2003). However, Sari and Soytas (2004) argue that the use of aggregate energy consumption or electricity consumption rather than utilizing different energy resources may be another reason behind the inconstancy in empirical studies results. It is possible that the importance of a certain energy resource for a country changes over time. Thus, empirical investigations require the use of different energy sources rather than aggregate energy consumption (Sari and Soytas (2004)). The lack of agreement on the direction of causality between energy consumption and economic growth has launched the idea of analyzing this relationship using different methodologies and disaggregated energy use measures. For example, Vaona (2012) tests for causality between energy use and GDP in Italy using three different approaches including Toda and Yamamoto (1995) procedure, the Johansen co-integration test, and the Lütkepohl et al. (2004) co-integration test. In his paper, energy has been disaggregated into renewable and non-renewable energy (fossil fuels). The main findings of Toda and Yamamoto test show that there is causation between non-renewable energy consumption and GDP, and between one measure of renewable energy and GDP. However, the standard procedure of Johansen test does not find co-integration between GDP and fossil fuels at all. Using and Lütkepohl et al. (2004) approach, Vona finds a co-integration relationship with a structural break. In the context of utilizing different energy sources rather than total energy use, few empirical studies have focused on investigating the causal relationship between oil consumption; which is the major daily traded energy source, and economic growth, on the one hand (Zou and Chau (2006); Zhao et al. (2008)), and between nuclear energy consumption and economic growth on the other (Wolde-Rufael and Menyah (2010); Yoo and Jung (2005);Yoo and Ku (2009)). Recenetly, there is an increasing interest to analyze the relationship between nuclear energy consumption and economic growth in energy economics literature. This is so, due to the increase in the importance of using nuclear energy in many countries as a mean of ensuring energy security, reducing emissions, coping with the increase in energy demand all over the world, and stabilizing oil price (Apergis et al. (2010)).

To analyze the causal link between energy consumption and economic growth and to tackle with the issues discussed above, this paper investigates the relationship between oil consumption, nuclear energy consumption, oil price, and economic growth in four emerging economies: Russia, China, South Korea and India, over the period from 1965 to 2010.[1] The analysis relies on a modified Wald (MWALD) test developed by Toda and Yamamoto (1995) that offer potential solutions to the methodological problems listed in Stern and Cleveland (2004). The Toda and Yamamoto (1995) approach eliminates the need for pre-testing for co-integration and therefore avoids pre-test bias and is applicable for any arbitrary level of integration for the series used. The main reason for studying the relationship between oil consumption, nuclear energy consumption and economic growth is that both oil and nuclear energy play an important role in designing effective energy policies that accounts for both economic growth and environmental protection and sustainable development. The empirical

[1] Most of the studies taken place so far concern developed countries (Esso, 2010).

results of relationship between nuclear energy, oil market and real GDP also play a pivotal role in the implementation of energy or environmental policies for both highly industrialised countries and emerging economies.

The rest of the paper is structured as follows. Section 2 describes the empirical model, Section 3 illustrates the definition of the variables, and data sources, and Section 4 provides the empirical results. A conclusion is provided in Section 5.

2. Empirical Model

Toda and Yamamoto (1995)procedure is a modified Wald test with restrictions on parameters of the four variable vector autoregression (VAR) model. This procedure overcomes those problems inherent in hypothesis testing that are often encountered when VAR processes have some unit roots. We conduct Granger causality testing with an allowance for the long-run information to be ignored in systems that require first-differencing and pre-whitening. This method is also valuable, because it eliminates the need for potentially biased pre-tests for unit roots and co-integration. Implementing TY (1995) procedure ensures that the usual test statistics for Granger causality has the standard asymptotic distribution where valid inferences can be made.

To undertake TY version of the Granger non causality test, this paper presents real output (RGDP), oil consumption (OC), Nuclear energy consumption (NC), and real oil prices (ROP) in the following four variable VAR system:

$$Z_t = \emptyset_0 + \pi_1 Z_{t-1} + \dots\dots\dots + \pi_k Z_{t-k} + U_t \qquad t = 1, \dots T, \qquad (1)$$

where $U_t \sim N(0, \Omega), Z_t = (RGDP_t, OC_t, NC_t, ROP_t)$. Economic hypothesis can be expressed as restrictions on the coefficients in the model in accordance with the following:

$$H_0 = F(\pi) = 0, \qquad (2)$$

where π = *vec (P)* is vector of parameters in Equation (1); $P = (\pi_1 \dots . \pi_k)$; and *F(.)* is a twice continuously differentiable $m - vector$ valued function.

Toda and Yamamoto (1995) suggest artificially augmenting the correct order, *k*, of VAR(k), where *k* is the lag length of the system, by the maximum number of integration, say d_{max}. Once this is done, a $(k + d_{\max})^{th}$ order of VAR is estimated and the coefficients of the last lagged d_{max} vectors are ignored. Clarke and Mirza (2006) show that, despite the additional parameters, this approach shows little loss power compared to alternative of testing the restrictions on a VECM that imposes co-integrating restrictions.

Assume that the maximum order of integration which is expected to characterize the process of interest is at most one, i.e., $d_{max} = 1$. Then in order to test hypothesis (2), one estimates the following VAR by OLS:

$$Z_t = \emptyset_0 + \pi_1 Z_{t-1} + \dots\dots\dots + \pi_k Z_{t-k} + \pi_p Z_{t-p} + U_t \qquad (3)$$

where $p \geq k + d_{max} = k + 1$, i.e., at least one more lag than the true lag length k is included. The parameter restrictions (2) do not involve the additional matrices$\pi_{k+1} \dots . \pi_p$, since these consist of zeros under the assumption that the true lag length is k.

3. Data

This paper uses annual data that covers the period from 1965 to 2010 for four emerging economies including Russia, South Korea, China, and India.[2] The variables employed include nuclear energy consumption per capita (NC), oil consumption per capita (OC), real gross domestic product per capita (RGDP), and real oil price (ROP). Both oil and nuclear energy consumption are obtained from BP Statistical Review of World Energy (2011) where NC is expressed in terms of Terawatt-hours (TWh) and OC is measured in thousand barrels daily. Oil consumption (OC) is the sum of island demand, international aviation, marine bunkers, oil products consumed in the refining process, and consumption of fuel ethanol and biodiesel. Real GDP per capita measured in constant 2005 US dollars and obtained from the World Development Indicators (WDI, 2011). Real oil prices are defined as the US dollar price of oil. Following Lee and Chiu Lee and Chiu (2011), oil price is converted to the domestic currency and then deflated by the domestic consumer price index (CPI), which is derived

[2] Russia's data covers the period from 1981 to 2010 only.

from International Financial Statistics (IFS, 2011) published by the International Monetary Fund (IMF). All data are expressed in logarithms in the empirical analysis.

4. Empirical Results

Before conducting any causality testing, it is important to determine the order of integration of the series; d_{max}, and the optimal lag length, k, to avoid any spurious causality or spurious absence of causality (Clarke and Mirza, 2006). To do this, this paper utilizes three different unit root tests including augmented Dickey and Fuller (1979) (ADF) test, Phillips and Perron (1988) (PP) test , and Kwiatkowski et al. (1992) (KPSS) test. Table 1 below reports the results of unit root tests, which indicates that the results are slightly contradictory. However, all variables are roughly non stationary at level and integrated of power one – I(1).

Table 1. Results of Unit root rests

Method	Variable	ADF	lags	PP (4)	PP (8)	KPSS(4)
Russia						
levels	ROP	-2.183	0	-5.461**	-5.922**	0.1072
	OC	-2.563	2	-0.63	-0.359	0.145
	NC	-0.99	0	-1.953	-1.791	0.121
	RGDP	-2.326	2	-0.934	-0.83	0.158*
first difference	ROP	-4.488*	0	-6.096**	-7.148**	0.144
	OC	-5.130**	4	-3.005	-2.778	0.109
	NC	-3.940**	0	-4.077*	-4.145*	0.087
	RGDP	-2.201*	0	-2.862	-2.709	0.09
China						
levels	ROP	-1.536	0	-1.729	-1.843	0.153*
	OC	-1.552	1	-2.859	-2.859	0.133
	NC	-1.751	1	-6.754**	-9.197**	0.114
	RGDP	-1.513	2	-2.443	-2.772	0.241**
first difference	ROP	-6.051**	0	-6.288**	-6.378**	0.118
	OC	-3.772*	0	-3.965*	-3.920*	0.141
	NC	-13.323**	0	-12.320**	-16.28**	0.124
	RGDP	-5.159**	0	-5.239**	-5.358**	0.085
South Korea						
levels	ROP	-2.086	0	-2.124	-2.253	0.126
	OC	-1.354	2	-3.556*	-3.479	0.194*
	NC	-1.495	0	-0.926	-0.594	0.177*
	RGDP	-0.799	0	-0.926	-0.594	0.191*
first difference	ROP	-7.668**	0	-8.048**	-7.960**	0.103
	OC	-3.714*	1	-3.485	-3.401	0.108
	NC	-4.478**	4	-3.823*	-3.756*	0.064
	RGDP	-6.190**	0	-6.434**	-6.443**	0.088
India						
levels	ROP	-2.136	0	-2.217	-2.176	0.143
	OC	-2.706	1	-2.987	-2.828	0.097
	NC	-0.896	1	-4.454**	-4.291**	0.065
	RGDP	1.118	4	0.967	1.467	0.025**
first difference	ROP	-6.962**	0	-7.243**	-7.279**	0.082
	OC	-6.316**	0	-6.583**	-7.127**	0.054
	NC	-9.373**	0	-10.46**	-12.54**	0.064
	RGDP	-5.350**	3	-8.220**	-8.586**	0.085

Notes: The regression includes an intercept and trend. All variables are in natural logarithms, while the lag length determined by Akaike Information Criteria and are in parentheses. ** indicates significance at the 5% level. The nulls for all tests except for the KPSS test are unit root.

In order to select the optimal lag length, k, Akaike, Hannan and Quinn, and Schwarz's Bayesian information criteria are used to build a decision as shown in Table 2 below.[3] Following Lütkepohl (1993) procedure, the max lag lengths (kmax) and the number of endogenous variables are linked with the sample size (T) according to the following formula: $m * kmax = T^3$. In the case of conflicting results, the choice is done based on AIC results as suggested by Pesaran and Pesaran (1997).

Table 2. lag selection criteria

Country	K	AIC	HQIC	SBIC
Russia	1	-1.82	-1.768	-1.623
	2	-8.443	-8.183	-7.461
	3	-9.553*	-9.084*	-7.786*
China	1	-11.081	-11.1664	-10.169
	2	-12.606	-12.758	-10.963
	3	-122.346	-122.566	-119.972
	4	-243.045*	-243.282*	-240.489*
South Korea	1	-7.918	-7.619*	-6.984*
	2	-7.771	-7.233	-6.089
	3	-8.097	-7.32	-5.669
	4	-8.577*	-7.561	-5.401
India	1	-8.744	-8.437*	-7.882*
	2	-8.667	-8.115	-7.116
	3	-8.316	-7.519	-6.076
	4	-8.831*	-7.789	-5.901

Notes: AIC, HQIC and SBIC stand for Akaike, Hannan and Quinn and Schwarz's Bayesian informa- tion criteria, respectively. In the case of conflicting results, we use AIC results as suggested by Pesaran and Pesaran (1997).

Having established the integration properties of the series and the length of VAR, the next step is to conduct Granger no causality test developed by Toda and Yamamoto (1995). Table 3 reports the results obtained from TY (1995) test, where the directions of causation are mixed. The main finding is that the emerging economies are highly sensitive to the level of world crude oil prices. There is a bi-directional causality between oil prices and real economic growth, and between oil prices and oil consumption for all countries except for India. This implies that sharp increase in oil prices has a direct negative impact on economic growth in these countries. Also, as these economies use a massive amount of energy to stimulate economic growth, this increase the demand of oil which accordingly affect the level of oil price, especially in the cases of oil supply disruption.

On the context of oil consumption and economic growth relationship, there is a bidirectional relationship between oil consumption and economic growth in India. This suggests that an increase in oil consumption directly affects economic growth, and that economic growth also encourages further oil consumption. In China and South Korea, there is a unidirectional causality running from economic growth to oil consumption. This finding is consistent with the paper developed by Zou and Chau (2006), who find that economic growth could be used as a predictive factor to forecast the long-run oil consumption in China. They suggest that this could be attributed largely to China's energy consumption structure. However, the results of South Korea in this concept are inconsistent with Yoo (2006), who has investigated the short and long run causality issues between oil consumption and

[3] In causality testing if the chosen lag is less than the true lag length, this can cause bias due to omitted relevant lags.

economic growth. He shows that there is a bi-directional causality running from oil consumption to economic growth.

Table 3. Granger non-causality test based on Toda and Yamamoto (1995)

Dependent variable	RGDP	OC	NC	ROP
Russia				
RGDP	-	3.828	1.435	7.563**
		(0.147)	(0.487)	(0.022)
OC	0.504	-	1.051	5.214*
	(0.777)		(0.591)	(0.073)
NC	0.689	0.101	-	8.927**
	(0.708)	(0.95)		(0.012)
ROP	7.328**	14.736***	1.035	-
	(0.025)	0	(0.595)	
China				
RGDP	-	1.876	1.523	16.639***
		(0.758)	(0.822)	(0.002)
OC	23.541***	-	21.370***	20.395***
	0		0	0
NC	10.969**	2.553	-	0.25
	(0.026)	(0.635)		(0.992)
ROP	8.792*	23.007***	4.797	-
	(0.066)	0	(0.308)	
South Korea				
RGDP	-	2.042	21.881***	43.361***
		(0.563)	0	0
OC	9.524**	-	11.116**	19.437***
	(0.049)		(0.025)	0
NC	6.606	2.349	-	3.621
	(0.158)	(0.671)		(0.459)
ROP	14.156***	45.943***	44.954***	-
	(0.006)	0	0	
India				
RGDP	-	11.559**	9.289*	4.575
		(0.029)	(0.054)	(0.334)
OC	15.446***	-	7.803*	4.199
	(0.006)		(0.099)	(0.379)
NC	6.12	5.603	-	3.848
	(0.191)	(0.231)		(0.427)
ROP	7.333	5.01	17.351***	-
	(0.119)	(0.286)	(0.001)	

Notes: *, ** and *** represent significant at the 10%, 5% and 1% levels, respectively. Significance implies that the column variable Granger causes the row variable. The reported estimates are the Wald statistics. The values in brackets are p-values.

Alternatively, findings with corresponding to nuclear energy consumption- growth nexus shown in Table 3 show that there is a unidirectional causal relationship running from nuclear energy consumption to economic growth without any feedback effect in South Korea, which is in line with the results of Yoo and Jung (2005) and Yoo and Ku (2009). This means that in order not to adversely affect economic growth, the Korean government should endeavour to overcome the constraints on nuclear energy consumption. Similarly, results obtained for India reveal that there is a unidirectional causal relationship running from nuclear energy consumption to real economic growth, which in line with Wolde-Rufael (2010).[4] Nevertheless, an opposite relationship is found in China.

5. Conclusion

Understanding the nature of relationship between energy consumption and economic growth is a key issue that both energy and environmental policy makers have to take into consideration to develop effective policies. While the linkage between energy consumption measures and economic growth has been examined for developed and developing countries, interaction between different energy sources, energy prices and economic growth received a little attention from researchers in literature (for instance, Asafu-Adjaye, 2000; Lee and Chiu, 2011a, b). Thus, this paper fills the gap by analyzing the long-run causal relationship between oil consumption, nuclear energy consumption, oil prices and economic growth in four emerging economies. In order to circumvent the issues associated with the power and size properties of unit root and co-integration tests, the Toda and Yamamoto (1995) test for long run causality is conducted over the period of 1965 to 2010.

The key finding of this investigation suggests that emerging economies do not support the neutrality hypothesis for neither oil consumption-growth nexus nor nuclear energy consumption-growth relationship except for Russia.[5] There is bidirectional causality between oil consumption and economic growth in India. In both China and Korea, there is a unidirectional causality running from real GDP growth to oil consumption with no feedback effect. This indicates that the quick expansion in their economies requires a rapid growth in oil consumption as well. Accordingly, there is strong evidence that the level of international oil price is very important for emerging economic activities. A bidirectional causality relationship between oil price and economic growth is detected in Russia, China, and Korea. Also, nuclear energy consumption is found to cause economic activity in Korea and India, while economic growth in China drives the use of nuclear power.

Overall, the study results of the existence of Granger causality between oil consumption and economic growth in major Asian emerging economies calls for caution and, has a number of implications for policy analysts and forecasters. A high level of economic growth leads to a high level of energy demand and/or vice versa. In order to deal with the lately concerns about the reliance on fossil fuels and not adversely affect economic growth, energy conservation policies that aim to curtailing energy use have to rather find ways of reducing demand on fossil fuel. Efforts must be made to encourage industries to adapt technology that minimize pollution. Alternatively, there is a keen interest in developing nuclear energy in many countries as a mean of ensuring energy security, reducing emissions, coping with the increase in energy demand all over the world, and stabilizing oil price.[6] Specifically, in this paper, there is a causal relationship running from oil price to nuclear energy consumption in three out of four industrialized countries, which implies that the upsurge of international crude oil price has a significant impact on nuclear energy development in these countries. However, nuclear safety is a global concern that needs a global solution. The right balance should be struck between the quest of economic growth, nuclear safety, clean energy and the drive towards making these countries relatively energy independent.

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[4] This result also consistent with Paul and Bhattacharya (2004), who investigate the causal linkage between energy consumption and economic growth in India, However; it is conflicting with the results of Soytas and Sari (2003), which show that there is no-causal linkage between energy consumption and economic growth in India.

[5] Although studies that examine economic growth in Russia are limited, it is shown that a 10% permanent increase (decrease) in international oil prices is associated with a 2.2% growth (fall) in the level of Russian GDP in the long run (Rautava (2004)). Here, there is indirect causal linkage between energy consumption (i.e., oil and nuclear energy) and economic growth through oil price channel, which has predictive contents to forecasts real GDP growth, oil and nuclear energy consumption.

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