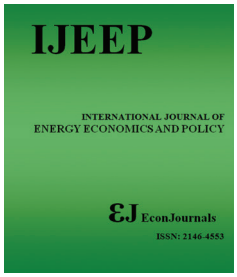

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Nuclear Energy Consumption and Economic Growth in G-6 Countries: Evidence from Bootstrap Rolling Window

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ABSTRACT

This study utilizes the bootstrap rolling window causality approach to investigate the causal linkage between nuclear energy consumption (NEC) and economic growth for different sample periods. Previous studies were based on assume of either causal or non-causal linkage availability for all sample periods. In order to determine the causality in each period, the bootstrap rolling window causality test is used in this study. The study concluded that a predictive power of NEC on economic growth exists only for Canada. Especially in United Kingdom, the "neutrality hypothesis" is supported strongly.

Keywords: Nuclear Energy Consumption, Economic Growth, G-6 Countries, Time Varying
JEL Classifications: O13, Q4

1. INTRODUCTION

Over the past two decades, most of the study examined the relationship between energy consumption and economic growth. Limited energy sources and the fluctuations of energy prices have led to the countries to search new renewable or nuclear energy sources. Since producing heat and electricity from nuclear energy consumption (NEC) does not emit carbon-dioxide and does not lead to environmental pollution, nuclear energy has become more important energy source.

In recent years, it seems that the studies on the relationship between NEC and economic growth based on the hypotheses which examine the relationship between energy consumption and economic growth. Four hypotheses have used in order to investigate the causal linkage between energy consumption and economic growth by Apergis and Payne, 2009; Payne, 2010; Ozturk, 2010; Tugcu et al., 2012. First hypothesis is called "growth hypothesis" and indicates that the unidirectional causal linkage exists from energy consumption to economic growth. According to this hypothesis a decrease in energy consumption leads to decrease in economic growth. The second one is that there is unidirectional causality relationship from economic growth to energy consumption. This hypothesis is called "conservation hypothesis." According to this hypothesis, decreased energy consumption may not be harmful on economic activities. Third hypothesis is called "feedback hypothesis" and this hypothesis argues that the bidirectional causality linkage exist between energy consumption and economic growth. According to the "feedback hypothesis," any conservation policy in energy consumption may be harmful on economic activities. Fourth hypothesis argues that there is no causal linkage between energy consumption and economic growth and this hypothesis is called "neutrality hypothesis." When neutrality hypothesis exist, conservation policy must be implemented.

Most of the studies examining the effects of both energy consumption and NEC on economic growth are based on these four hypothesis but these studies assume that the causal or non-causal linkage exist for all sample years. Balcilar et al. (2010) argue that the causality relationship between energy consumption and economic growth may be exist for only subperiods and also argue that this causal linkage must be investigated with time varying causality (rolling window causality) test.

The main aim of this study is to investigate the relation among NEC and economic growth with bootstrap rolling window causality for G-6 countries. Although there is no causal relationship between NEC and economic growth for all sample periods, it may be exist for some subperiods. For this purpose, finding the

subperiods which show the causal relations and nuclear energy policies of these periods can lead to more reliable results for policy implications.

The rest of the paper is organized as follows; the next section gives the studies and findings about energy consumption and renewable energy in relation to the economic growth. In third section, the data used in empirical analysis and empirical methods are described. The results of empirical analysis are transferred in 4th section. Finally, in the fifth section conclusions and policy implications are given.

2. LITERATURE REVIEW

Some of the studies have supported different hypothesis since Kraft and Kraft's (1978) pioneer study which has concluded that a unidirectional causality from economic growth to energy consumption for 1947-1974 period in the US but Ozturk (2010) argues that the different results on energy consumption and economic growth nexus may be sourced from different econometric methods or different sample periods.

Narayan and Smyth (2008), examine the relationship between energy consumption and growth in G7 countries with the panel cointegration and panel causality methods from 1972 to 2002; Bowden and Payne (2009) in their study examining 1949-2006 period for the United States with Toda–Yamamoto procedure and the results of these studies have supported "growth hypothesis." Similarly, Soytas and Sari (2003) found unidirectional causality from energy consumption to economic growth in Turkey, France and Germany, Apergis and Payne (2010), in their study examining the 1992-2004 period for 11 countries by panel cointegration and panel fully modified ordinary least squares methods, Fuinhas and Marques (2011), in their study covering the years 1965-2009 for Portugal, Italy, Greece, Spain and Turkey; Kaplan et al. (2011), in their study covering the years 1971-2006 for Turkey; Raza et al. (2015), in their study covering the 1973-2013 period and benefiting from auto regressive distributive lag (ARDL) approach for Pakistan; Kyophilavong et al. (2015), using vector error correction model (ECM) Granger approach and the years from 1971 to 2012 for Thailand; Osigwe and Arawomo (2015), using ECM framework for 1970-2012 period in Nigeria have reached supportive results of "feedback hypothesis." Huang et al. (2008), examining the causal linkage for 1972-2002 period in 82 countries with generalised method of moments method; Shahbaz and Feridun (2012) investigate in Pakistan, have supported "energy conservation hypothesis." Soytas et al. (2007) have supported "the neutrality hypothesis" as a result of their study 1960 to 2004 period for the United States. In analogy with the purpose of this study, Balcilar et al. (2010), have utilized with rolling window causality and concluded that the causal linkage between energy consumption and economic growth is not exist for most of the sample periods in G7 countries except of Canada. In Canada, they found energy consumption Granger-cause economic growth for most of the sample periods.

The studies which investigate the relationship between NEC and economic growth are less. Yoo and Jung (2005) examined the causal linkage between NEC and economic growth in Korea and supported the "growth hypothesis." Similarly, Apergis and Payne (2010) supported the "growth hypothesis" in the long-run. Nazlioglu et al. (2011) supported the "feedback hypothesis" for 14 Organization for Economic Cooperation and Development (OECD) countries while Menyah and Wolde-Rufael (2010) investigated this linkage in the US and supported the "neutrality hypothesis." The results of some studies show that mixed hypotheses are available such as Wolde-Rufael and Menyah (2010) supported "growth hypothesis" in Japan, Switzerland and Netherlands while they supported the "conservation hypothesis" in Sweden and Canada. Further, in their study, the "feedback hypothesis" was supported in the UK, the US, France and Spain. Similarly, Omri and Chaibi (2014) examined for 17 developed and developing countries and "growth hypothesis" was supported in Belgium and Spain; "conservation hypothesis" was supported in Bulgaria, Canada, Sweden and Netherlands; "neutrality hypothesis" was supported in Finland, Hungary, Japan, India, Switzerland and the UK; "feedback hypothesis" was supported in Brazil, Argentina, France, Pakistan and the US.

Furthermore, there are some studies have mixed results such as Naser (2014), using Toda–Yamamoto procedure for 1965-2010 period in four emerging economies (Russia, China, South Korea and India) and concluded that NEC leads to economic growth in both South Korea and India; Naser (2015), has utilized with Toda–Yamamoto procedure for highly industrialized countries such as Canada, the US, Japan and France and it is concluded that the "neutrality hypothesis" exists for the US and Canada while the "growth hypothesis" exists for Japan. In analogy with this study, Chu and Chang (2012), investigated the relationship between NEC and economic growth with panel causality approach for G-6 countries covering the years from 1971 to 2010 and the results of this study supported the "feedback hypothesis" for the US, the "growth hypothesis" for the UK and Japan and the "neutrality hypothesis" for Canada, France and Germany.

3. DATA AND METHODOLOGY

As regards to the data employed in this study, the annual data is collected for the period 1965-2013 for the US, France and United Kingdom but due to the lack of data availability 1971-2013 period is used for Canada, 1970-2013 period is used for Germany and 1966-2013 period is used for Japan. The variables used in this study covers real gross domestic product (GDP) (Y) in billion of constant 2005 US $ and NEC is used in terms of Terawatt-hours. The data of real GDP is sourced from World Development Indicators 2015 (World Bank) and NEC data is sourced from British Petroleum Statistical Review of World Energy (BP, 2014). All variables are in natural logarithms.

First, in order to examine stationary properties to determine the order of integration of variables is crucial for cointegration analysis. In this study, Ng and Perron (2001) unit root test is used as a unit root test. Ng–Perron unit root test is developed to modify size distortion of Phillips and Perron's (1988) unit root test. Ng–Perron unit root test includes four statistics such as MZ_a and MZ_t statistics which are modified of Phillips–Perron's Z_a and

Z_t statistics, *MSB* statistic is modified of Bhargava test and *MPT* statistic is modified of ADF-GLS test.

In order to define the bootstrap Likelihood Ratio Granger causality test, consider the following bivariate vector autoregressive (p) process:

$$Z_t = \phi_0 + \phi_1 Z_{t-1} + \ldots + \phi_p Z_{t-p} + \varepsilon_t, t = 1,2,...T \quad (1)$$

Where, p is the lag order, $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ is zero mean white noise process and covariance matrix ΣZ_t is splited in two sub-vectors, NEC (Z_{1t}) and GDP (Z_{2t}), therefore obtain;

$$\begin{bmatrix} Z_{1t} \\ Z_{2t} \end{bmatrix} = \begin{bmatrix} \phi_{10} \\ \phi_{20} \end{bmatrix} + \begin{bmatrix} \phi_{11}(L) & \phi_{12}(L) \\ \phi_{21}(L) & \phi_{22}(L) \end{bmatrix} \begin{bmatrix} Z_{1t} \\ Z_{2t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \quad (2)$$

Where, $\phi_{ij}(L) = \sum_{k-1}^{p} \phi_{ij,k} L^k, i, j = 1,2$ and L is the lag operator such as $L^k x_t = x_{t-k}$ that is to say, the null hypothesis that GDP does not Granger-cause NEC can be investigated by imposing the zero restrictions $\phi_{12,i} = 0$ for I = 1, 2…, p and similarly the null hypothesis that NEC does not Granger-cause GDP can be examined by imposing the restriction $\phi_{21,i} = 0$ for i=1, 2,…, p. The bootstrap testing approach developed by Efron (1979), which generates critical values from the empirical distribution and associate this with Toda and Yamamoto (1995) causality test's modified version which applies to both non-cointegrated and cointegrated I (1) variables (Hacker and Hatemi-J, 2006). Balcilar et al. (2010)'s the bootstrap causality test to rolling window sub-samples for t=τ−l+1, τ−l,…, τ,τ=l, l+1,…,T, where l is the rolling window, is developed in order to detect structural breaks. In this study, the bootstrap rolling window causality test is used as a causality test in order to examine the causal relationship between NEC and GDP. Furthermore, following Balcilar et al. (2010) and Aye et al. (2014), the *P*-values are obtained from 10000 bootstrap and 15% of the sample is trimmed.

4. EMPIRICAL RESULTS

In this article, first Ng and Perron (2001) unit root test is used in order to investigate the stationary properties of variables. After, to determine the causal linkage between variables the bootstrap rolling window causality approach is applied.

4.1. Unit Root Test

Ng and Perron (2001) unit root test results are displayed in Table 1. It can be seen from Table 1, the null hypothesis that the NEC series have unit root process cannot be rejected according to the Z_a and MZ_t test statistics for all countries. Similarly, the null hypothesis that GDP series have unit root cannot be rejected at 10% significance level. At first difference, both NEC and GDP series become stationary and the null hypothesis can be rejected for all countries.

4.2. Causality Test

Since all series become stationary at their first differences, the bootstrap rolling window causality test can be applied in order to examine the causal relationship between NEC and economic growth in G-6 countries such as Canada, France, Germany, Japan, United Kingdom and United States.

Table 1: Ng and Perron unit root test results

Country	Level		First difference	
	Z_a^a	MZ_t^a	Z_a^b	MZ_t^b
Panel A: NEC				
Canada	−3.448	−1.207	−10.249**	−2.234**
France	−7.796	−1.826	−3.027**	−3.384**
Germany	−13.292	−2.446	−16.610***	−2.879***
Japan	−0.006	−0.003	−16.993***	−2.640***
United Kingdom	−2.139	−0.820	−16.963***	−2.877***
United States	0.194	0.158	−6.817*	−1.776*
Panel B: GDP				
Canada	−11.718	−2.298	−16.442***	−2.842***
France	−3.517	−1.083	−13.516**	−2.495**
Germany	−3.094	−0.988	−20.088***	−3.125***
Japan	0.323	0.187	−11.120**	−2.253**
United Kingdom	−5.830	−1.492	−21.504***	−3.277***
United States	−4.250	−1.137	−16.843***	−2.871***

Note: *,** and *** indicate significance at 10%, 5% and 1% level statistically, [a]test allows for constant and trend, [b]test allows for constant, GDP: Gross domestic product, NEC: Nuclear energy consumption

4.2.1. Canada

Figure 1 presents the bootstrap *P*-values of the rolling test statistics, testing the null hypothesis that NEC does not Granger cause economic growth is rejected during the 2007 and 1986-1992 subperiods. On the other hand, according to Figure 2 the null hypothesis that economic growth does not Granger cause NEC cannot be rejected for most of the periods in Canada. The only rejections are during the 1988-1989 and 2011-2013 subperiods.

It is known that the National Research Universal reactor which was the first reactor built at Chalk River in 1957. Canada generated 102.8 billion kWh from nuclear power as a share in total generating capacity was %15.8 in 2013. Further, through Canada's nuclear program over 1952-2006 the government invested C$ 13.26 billion (in 2005 dollars) (World-Nuclear, 2015a). It can be said that the nuclear program of the government of Canada was positively effect on Canada's economy.

4.2.2. France

The estimation results for France are plotted in Figures 3 and 4. Figure 3 indicates that the null hypothesis that NEC does not Granger-cause economic growth is rejected in the 1987-1988 and 1997-1998 subperiods and in 2007 at 10% significance level, while the null hypothesis is not rejected during the rest of the sample period. Figure 4 shows that the null hypothesis that economic growth does not Granger-cause NEC can't be rejected most of the periods except of 1995 and 1997.

It is the well-known fact that France is very active in nuclear technologies. Nuclear energy generates approximately 75% of France's electricity (Brunnengraber and Schreurs, 2015). Since the low cost of electricity generation by nuclear energy, France is world's largest net exporter of electricity (World-Nuclear, 2015b). It can be seen that the nuclear policies of France leads to positive impacts on economic growth because of the "growth hypothesis" is supported in some subsample periods.

Figure 1: From nuclear energy consumption to economic growth (Canada)

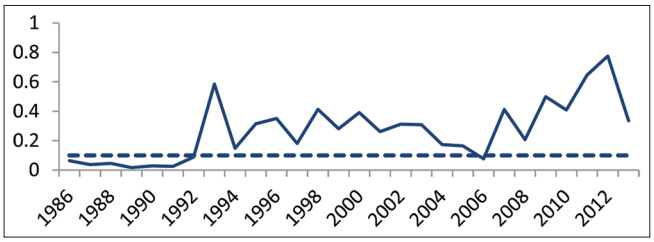


Figure 2: From economic growth to nuclear energy consumption (Canada)

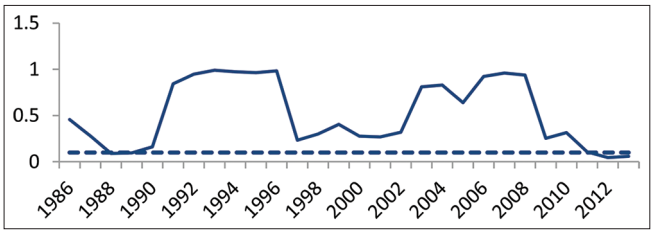


Figure 3: From nuclear energy consumption to economic growth (France)

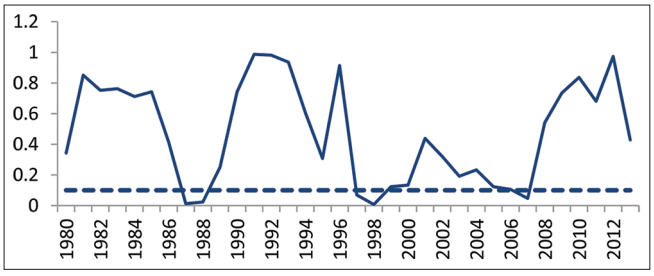
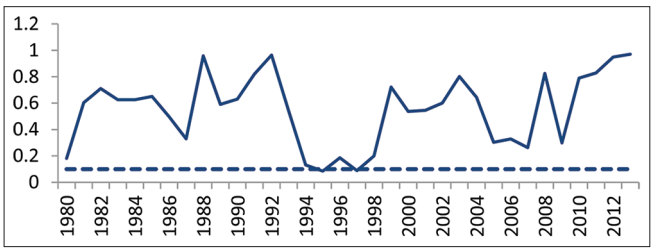


Figure 4: From economic growth to nuclear energy consumption (France)



4.2.3. Germany

The causality relationship between NEC and economic growth is illustrated in Figures 5 and 6. While the null hypothesis that NEC does not Granger-cause economic growth is rejected only in 2004 and 2010, the causality from economic growth to NEC exists in 1985-1989, 1995-1996 and 2000-2001 subperiods.

The German Federal Government signed a contract in order to phase out nuclear energy by 2022 in 2000 but the debates on the future of nuclear energy started again in recent years. It is claimed that prices would be lower if implementation of this contract is delayed (Nestle, 2012). The result of our analysis shows that there are unidirectional causalities from economic growth to NEC and those findings implies that the "conservation hypothesis" is exist

Figure 5: From nuclear energy consumption to economic growth (Germany)

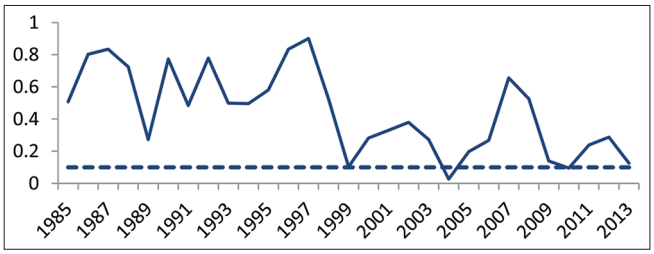
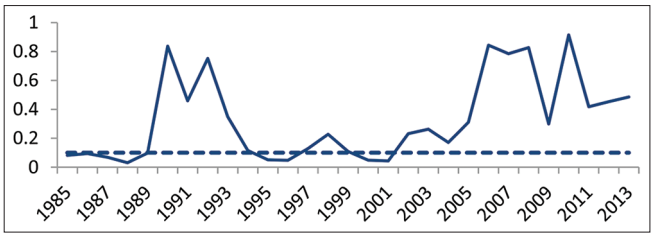


Figure 6: From economic growth to nuclear energy consumption (Germany)



in some sub periods. Based on those findings, it can be said that the nuclear energy conservative policies would be positive for economic activities of Germany.

4.2.4. Japan

The plot shown in Figure 7 suggests that NEC does not have powerful effect on economic growth during the sample period, with the exception of the 1992 and 2003. The plot of bootstrap *P*-values of LR test statistic shown in Figure 8 implies the null hypothesis that economic growth does not Granger-cause NEC. The evidence from the plot indicates that the null hypothesis is not rejected over the most of the sample period with the exception of five periods which are 1988, 2001, 2002, 2008 and 2011.

4.2.5. The United Kingdom

For United Kingdom, the results shown in Figures 9 and 10 imply that both causality from NEC to economic growth and from economic growth to NEC do not exist in the all sample periods. These findings support "neutrality hypothesis" in United Kingdom therefore it can be said that the reduction in NEC would noıt be harmful on economic activities of the UK.

4.2.6. US

Figure 11 shows that the null hypothesis that NEC does not Granger-cause economic growth is rejected in the 1988-1989, 1993, 2002, 2004-2005 subperiods. Furthermore, the bootstrap *P*-values of rolling test statistic shown in Figure 12 fail to reject the null hypothesis that economic growth does not Granger-cause NEC at 10% significance level over the most of period except of 1988-1989, 1998-1999 and 2006 subperiods.

Apparently, the results of this study are not consistent with earlier studies such as Naser (2015); Chu and Chang (2012) found the neutrality hypothesis for Canada. In this study, it is concluded that there is unidirectional causality from NEC to economic growth in Canada for large subsample periods. Further, Payne and Taylor

Figure 7: From nuclear energy consumption to economic growth (Japan)

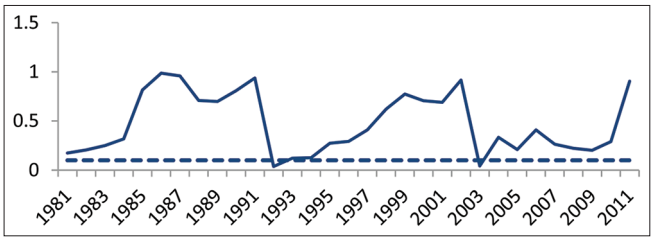


Figure 8: From economic growth to nuclear energy consumption (Japan)

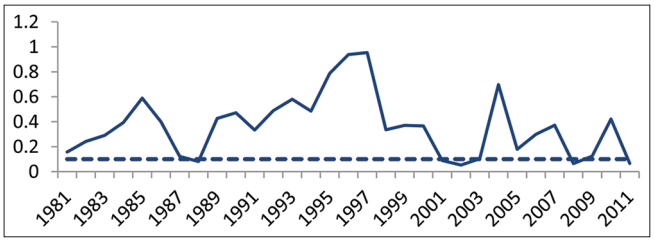


Figure 9: From nuclear energy consumption to economic growth (The UK)

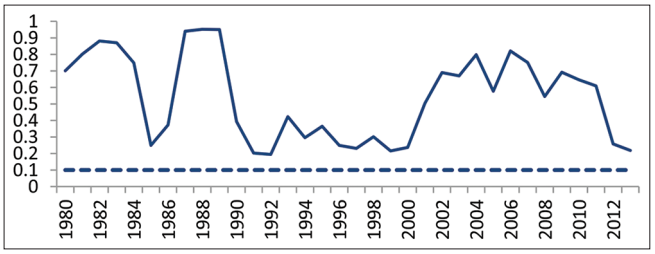


Figure 10: From economic growth to nuclear energy consumption (The UK)

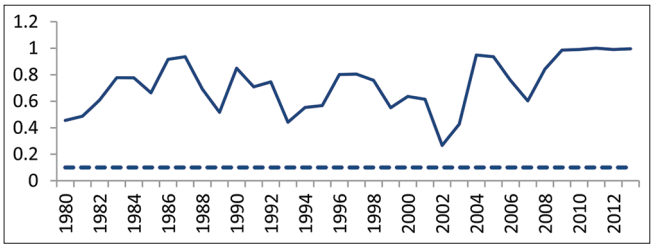
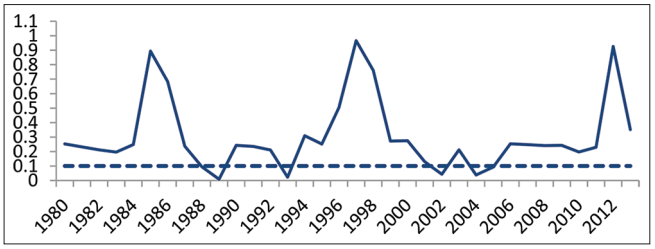
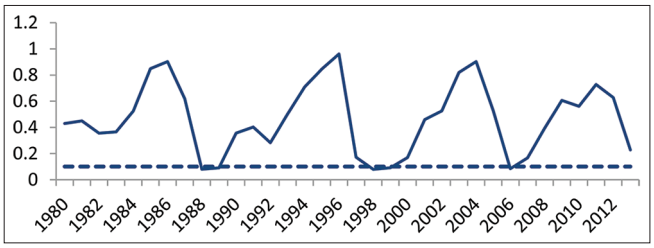


Figure 11: From nuclear energy consumption to economic growth (The US)



(2010); Menyah and Wolde-Rufael (2010); Naser (2015) have supported the availability of neutrality hypothesis for the US while the growth hypothesis is supported for the US in this study. Similarly the findings of this study show different results for Japan when compared with Lee and Chiu (2011). However, the results of this study is consistent with Chu and Chang (2012), they found the unidirectional causality relationship from NEC to economic growth for the UK in analogy with this study.

Figure 12: From economic growth to nuclear energy consumption (The US)



5. CONCLUSIONS AND POLICY IMPLICATIONS

In this study, the relationship between NEC and economic growth in G6 countries (Canada, France, Germany, Japan, United Kingdom and United States) is examined. Due to the fact that the causality linkage between these factors does not exist for all sample periods the rolling window causality (time varying causality) approach is used as an empirical method.

According to the causality test results, NEC is more efficient on economic growth in Canada, France and the US when compared with remaining G-6 countries. These results are not surprising due to the fact that Canada and the US are main uranium producer countries.

In Germany, it can be said that the "conservation hypothesis" exists for some subsample periods. In remaining G-6 countries, there is no causality linkage between NEC and economic growth in most of the sample periods however strong unidirectional or bidirectional causality relations are observed for some subperiods. These findings can be associated with various economic changes such as increased employment in nuclear power plants or increased export of medical radioisotopes. To sum up, the "neutrality hypothesis" is strongly supported in Japan and the UK for most of the sample periods however the "growth hypothesis" is supported especially in Canada for the large subperiods. But still it would not be right to argue that the conservation policies on NEC due to the fact that the other G-6 countries' nuclear investments have been started later than Canada.

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