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CO_2 emissions, nuclear energy, renewable energy and economic growth in the US

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ABSTRACT

This study explores the causal relationship between carbon dioxide (CO_2) emissions, renewable and nuclear energy consumption and real GDP for the US for the period 1960–2007. Using a modified version of the Granger causality test, we found a unidirectional causality running from nuclear energy consumption to CO_2 emissions without feedback but no causality running from renewable energy to CO_2 emissions. The econometric evidence seems to suggest that nuclear energy consumption can help to mitigate CO_2 emissions, but so far, renewable energy consumption has not reached a level where it can make a significant contribution to emissions reduction.

1. Introduction

It is now widely recognised that unless drastic actions are taken to reduce global warming, the world could be heading not only towards reduced growth but also more importantly towards environmental disaster (Stern, 2007; Adamantiades and Kessides, 2009; DeCanio, 2009; Reddy and Assenza, 2009). Stern (2007) estimates that the economic impact of global warming could reduce global GDP by as much as 25%, while greenhouse gas mitigation would cost about 1% of the global GDP. Equally, the energy security problem facing energy-importing countries is also daunting (Hedenus et al., 2010). The high degree of concentration of energy supply sources in the volatile region of the Middle East, where over 68% of oil reserves are located clearly involves risks for the US in terms of the reliability of its supply of energy needs (Gnansounou, 2008).

The environmental challenge facing the US including many other imported-energy-dependent countries is how to increase sectoral energy supplies to produce more secure and cheap energy, and at the same time, how to reduce greenhouse gas emissions (GHG). Any attempt at dealing with global warming requires finding sources of energy alternatives to fossil fuels. Both renewable (hydro, wind, solar, biomass and geothermal) and nuclear energy sources are believed to provide some solutions to the pr9oblems of energy security and climate change. Like many other countries, as part of its strategy of increasing energy security and dealing with global warming, the US is investing in nuclear and renewable energy not only to reduce dependence on imported oil but also to increase the supply of secure energy, to minimize the price volatility associated with oil imports and to reduce greenhouse gas emissions (Toth and Rogner, 2006; Vaillancourt et al., 2008; Adamantiades and Kessides, 2009). The advantage of using nuclear and renewable energy has also become even more pressing as a result of the Kyoto Agreement that requires signatories to cut back substantially on their emissions of CO_2 in order to reduce global warming (Becker and Posner, 2005). The Kyoto Protocol places an obligation on all signatories to ensure that GHG emissions in 2012 are not greater than the total of such emissions in 1990. The possible avenues for reduction in GHG emissions include the use renewable and nuclear sources of energy. Many believe that both renewable and nuclear energies, as virtually carbon free energy sources, could provide a major solution to global warming and energy security (Elliot, 2007 and Ferguson, 2007). It is therefore not surprising to see that these serious concerns over rising fossil fuel prices, energy security, and greenhouse gas emissions have brought the importance of both renewable and nuclear energies to the forefront of the wider issue of the energy debate (Adamantiades and Kessides, 2009). Even countries that were sceptical in the past about nuclear energy are now showing a keen interest in developing nuclear energy as a means of diversifying energy

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supplies, improving energy security, and as a means of providing a low-carbon energy alternative to fossil fuels (International Energy Agency, IEA, 2008; Adamantiades and Kessides, 2009; Wolde-Rufael, 2010). Unlike in the past, there are now some concrete proposals within the US to build new nuclear energy plants, and the prospects of expanding renewable energy are also looking more viable than assumed earlier (Paltsev et al., 2009).

It is claimed that the operation of nuclear plants worldwide makes a significant contribution to the mitigation of GHG emissions where currently nuclear plants save some 10% of CO_2 emissions from world energy use (Adamantiades and Kessides, 2009). According to the Nuclear Energy Agency (2002), over the past 40 years nuclear power plants have already played a major role in lowering the amount of greenhouse gases produced by the electricity sector in OECD countries. It is further claimed that without nuclear power, the OECD power plant emissions of carbon dioxide would have been about one-third higher than they are at present. Estimates made by the Nuclear Energy Agency (2002) also suggest that nuclear plants save annually some 1200 million tonnes of carbon dioxide, or about 10% of total CO_2 emissions from energy use in OECD countries. Moreover, the European Union (2006) also believes that Europe would not have been able to make any significant impact on reducing CO_2 emissions without relying on nuclear energy. However, sceptics warn that while the combination of several factors mentioned above makes nuclear energy a creditable alternative source of energy and one of the potential panaceas for greenhouse gas reduction, its enormous risks are also equally substantial (Toth and Rogner, 2006; Elliot, 2007, Ferguson, 2007; World Energy Council, 2007; Squassoni, 2009; Adamantiades and Kessides, 2009; Wolde-Rufael, 2010).

While there have been numerous studies that have investigated the causal relationship between energy consumption and economic growth, and between energy consumption and pollutant emissions [(see, Dinda, 2004; Chontanawat et al., 2008; Payne, 2010a,b; Ozturk, 2010; Aslanidis and Iranzo, 2009)], to the knowledge of the present authors, there seems to be no empirical research that has attempted to test the causal relationship between nuclear energy consumption, renewable energy and CO_2 emissions using modern advances in time series econometrics of integration and causality. Thus, the importance of nuclear and renewable energy supplies as potential sources of mitigating greenhouse gases emission necessitates a research that investigates the causal link between these two energy sources and CO_2 emissions.

The aim of this paper is to investigate the causal link between nuclear energy consumption, renewable energy consumption and CO_2 emissions for the US for the period 1960–2007. The US is chosen for the following few reasons. In the first place, both renewable and nuclear energies consumption account for a significant portion of the overall primary energy consumption in the US accounting for almost 16% of the overall energy consumption in 2008, with nuclear energy consumption accounting for 8.5% and renewable energy consumption accounting for 7.3% in 2008. Secondly, the US is the single largest emitter of CO_2 (soon China will overtake) and the chances for achieving any meaningful global agreement on climate changes critically depends on the US (DeCanio, 2009). Thirdly, the dependence of the US on fuel consumption and its contribution to climate change due to emissions of greenhouse gases has been an important energy and environmental issue confronting the country (Payne, 2009). The alleged cost to the economy has been preventing the US from ratifying the Kyoto Protocol and also has made her hesitant from making economic sacrifices to combat CO_2 emissions. Fourthly, the US has developed a nuclear regulation and supervision system believed to be the most elaborate and demanding, which can set an example for the rest of the world to follow (Adamantiades and Kessides, 2009).

The rest of the paper is organised as follows: in Section 2 we present the data and methodology followed in Section 3 by the empirical evidence. Summary and concluding remarks are presented in Section 4.

2. Data and methodology

The empirical evidence presented in this paper is carried out using the Toda and Yamamoto (1995, here after TY) version of the Granger non-causality test. This approach fits a standard vector auto-regression model on levels of the variables (not on their first differences) that give allowances for the long-run information often ignored in systems that require first differencing and pre-whitening (Clarke and Mirza, 2006; Rambaldi and Doran, 2006). The TY procedure employs a modified Wald test (MWALD) for restriction on the parameters of the VAR (k) where k is the lag length of the system. The basic idea of the TY approach is to artificially augment the correct order, k, by the maximal order 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 (see Caporale and Pittis (1999)). As we are more interested in the relationship between CO_2 emissions, nuclear energy consumption and renewable energy consumption, the equations corresponding to each of these dependent variables are presented below

$$\ln C_t = \alpha_0 + \sum_{i=1}^{k}\alpha_{1i}\ln C_{t-i} + \sum_{j=k+1}^{\text{dmax}}\alpha_{2j}\ln C_{t-j} + \sum_{i=1}^{k}\beta_{1i}\ln N_{t-i} + \sum_{j=k+1}^{\text{dmax}}\beta_{2j}\ln N_{t-j} + \sum_{i=1}^{k}\nu_{1i}\ln R_{t-i} + \sum_{j=k+1}^{\text{dmax}}\nu_{2j}\ln R_{t-j} + \sum_{i=1}^{k}\phi_{1i}\ln Y_{t-i} + \sum_{j=k+1}^{\text{dmax}}\phi_{2j}\ln Y_{t-j} + \varepsilon_{1t} \tag{1}$$

$$\ln N_t = \upsilon_0 + \sum_{i=1}^{k}\delta_{1i}\ln C_{t-i} + \sum_{j=k+1}^{\text{dmax}}\delta_{2j}\ln C_{t-j} + \sum_{i=1}^{k}\lambda_{1i}\ln N_{t-i} + \sum_{j=k+1}^{\text{dmax}}\lambda_{2j}\ln N_{t-j} + \sum_{i=1}^{k}\pi_{1i}\ln R_{t-i} + \sum_{j=k+1}^{\text{dmax}}\pi_{2j}\ln R_{t-j} + \sum_{i=1}^{k}\varpi_{1i}\ln Y_{t-i} + \sum_{j=k+1}^{\text{dmax}}\varpi_{2j}\ln Y_{t-j} + \varepsilon_{2t} \tag{2}$$

$$\ln R_t = \theta_0 + \sum_{i=1}^{k}\theta_{1i}\ln C_{t-i} + \sum_{j=k+1}^{\text{dmax}}\theta_{2j}\ln C_{t-j} + \sum_{i=1}^{k}\varphi_{1i}\ln N_{t-i} + \sum_{j=k+1}^{\text{dmax}}\beta_{2j}\ln N_{t-j} + \sum_{i=1}^{k}\zeta_{1i}\ln R_{t-i} + \sum_{j=k+1}^{\text{dmax}}\zeta_{2j}\ln R_{t-j} + \sum_{i=1}^{k}\rho_{1i}\ln Y_{t-i} + \sum_{j=k+1}^{\text{dmax}}\rho_{2j}\ln Y_{t-j} + \varepsilon_{3t} \tag{3}$$

Where $\ln C_t$ is the log of CO_2 emissions (measured in kt of oil equivalent), $\ln R_t$ is the log renewable energy consumption (measured in billion Btu); $\ln N_t$ is the log nuclear energy consumption (measured in billion of Btu) and $\ln Y_t$ is the log of real GDP (proxy for economic growth). All data are annual for 1960–2007. Real GDP at 2000 constant prices and CO_2 emissions are taken from the World Bank, World Development Indicators, 2008. Nuclear energy consumption and renewable energy consumption are from the online database of the US Energy Information Administration. Following Apergis and Payne (2010) and Sadorsky (2009), renewable energy consumption includes net geothermal, solar, wind, and wood and waste electric power consumption (Energy Information Administration, 2009a, 2009b). We include real GDP because both real GDP and CO_2 emissions are found to be important drivers of renewable energy consumption (Sadorsky, 2009; Apergis and Payne, 2010). Per-capita income is also the most important determinant of CO_2 emissions. There is