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Does Nuclear Energy Consumption Improve Environment? Empirical Evidence From India

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ABSTRACT

This paper attempts to investigate the long run and short run relationship between nuclear energy consumption and carbon dioxide emission in India within energy consumption growth-environment deterioration framework, over the period of 1969-2014 using a multivariate model wherein coal consumption, oil consumption and trade openness are also included as additional variables. The empirical results indicate that there is a long run relationship among the competing variables. We find that nuclear energy consumption indeed reduces CO_2 emission in both short run and long run in India. On the other hand, non-renewable energy sources (oil and coal) increase CO_2 emission in both long run and short run. Based on these findings, it is suggested that government should shift from non-renewable energy sources to nuclear energy to attain faster, inclusive and sustained economic growth.

INTRODUCTION

Carbon dioxide emissions, especially through use of non-renewable energy sources (like oil and coal) is a major reason of global warming, imposing serious threat to the environment. The effect of economic activities on CO_2 emission has been a critical issue, both at the national and international level. The depletion of non-renewable energy sources and their negative impact on environment, however, have recently attracted a wide attention towards developing alternative energy sources (Ohlan 2016). Another important concern regarding environmental degradation is how to make balance between sustained economic growth without increasing CO_2 emission in emerging economies like India. India has emerged as the third largest economy in the world in terms of nominal gross domestic product and has a potential to rise rapidly in near future. But economic growth in India is mainly driven by dirtiest energy matrix. India ranked 3rd largest country in the world in terms of CO_2 emission from coal consumption (2166 mt) after China and United States. India has 6.56 percent share in terms of CO_2 emission in the world. India holds second position in coal and lignite consumption and 3rd position in oil consumption in the world. Although India is home for 18 percent of the world's population, but it has only 0.6%, 0.4% and 7% of the world's oil, gas and coal reserves, respectively. Consequently, the country's dependence on energy imports is expected to increase. Approximately 70 percent electricity in India is generated by using fossil fuel. Out of the total energy consumption, the share of coal is about 40%, while oil accounts for about 24%. Moreover, the share of oil import is 31 percent of the total imports. Thus, energy demand in India is expected to rise steadily in coming years to meet the requirement of economic growth (Vidyarthi 2013). Despite having notable fossil fuel resources, India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption till 2030. India's energy sector is becoming increasingly susceptible to global supply disruptions and volatility in international price. There is an urgent need to find the alternate source of energy to meet the expected energy demand in the near future in India.

Therefore, nuclear energy could be one of the best alternate of energy consumption in India to fulfil the energy demand. Nuclear power is the fourth largest source of electricity in India after thermal, hydroelectric and renewable sources of electricity. India has 21 nuclear reactors in operation in 7 nuclear power plants, having an installed capacity of 6780 MW. However, nuclear power plants account for 3.5% of India's current electricity generation. First nuclear power plant in India was constructed in 1970. Currently, there are six operative nuclear power reactors, and two advanced reactors are under construction. India is at 4th position in nuclear energy consumption in the world. According to a report published by International Atomic Energy Agency (IAEA), India ranked at 12th position in terms of power generation from nuclear sources in 2015. However, it holds 6th position in terms of number of reactors in operation country-wise, globally. In order to strengthen nuclear energy programmes, India has signed 123 nuclear agreements with USA.

Numerous studies have investigated the relationship between nuclear energy consumption and economic growth (Apergis & Payne 2009, 2010, Heo et al. 2011, Lee & Chiu 2011, Lin et al. 2014, Wolde-Rufael 2010, Wolde-Rufael & Menyah 2010). The second group of studies tested the significant factors of CO_2 emission in developed and developing nations (Alam et al. 2016, Farhani et al. 2014, Gökmenoglu & Taspinar 2016, Jalil & Mahmud 2009, Lee & Yoo 2016, Ohlan 2015, Ozturk & Uddin 2012, Peng et al. 2016, Saboori & Sulaiman 2013, Saboori et al. 2012, Saidi & Hammami 2015). Most of these studies found economic growth, energy consumption, trade openness and FDI as a key determinant of CO_2 emissions.

Despite several studies examined the relationship between energy consumption and CO_2 emission, there are only a few studies that have examined the nuclear energy-CO_2 relationship. A recent study is conducted by Baek (2016) to explore the dynamic effects of nuclear and renewable energy consumption on carbon emission in United States over the period of 1960-2010. The main outcome of the study is that nuclear energy consumption reduces CO_2 emissions in both short run and long run. Another study is conducted by Al-Mulali (2014) to explore the influence of nuclear energy consumption on economic growth and carbon dioxide emission in 30 major nuclear energy consuming countries for the period of 1990-2010. The main finding of the study is that nuclear energy consumption has a positive long run effect on GDP growth while it has no long run effect on CO_2 emission.

This study attempts to investigate the impact of nuclear and non-renewable energy consumption on CO_2 emission in India. Although several studies have examined the relationship between energy consumption and economic growth in the past two decades, empirical studies exploring the relationship between nuclear energy consumption and CO_2 emission in India are non-existent. This study is different from earlier studies as it is the first attempt to examine the impact of nuclear energy consumption on CO_2 emission in India by considering short run and long run relations.

METHODOLOGY

The study employs Autoregressive Distributive Lag Model (ARDL) to ascertain the influence of both nuclear energy and non-renewable energy consumption on CO_2 emission in India over the period of 1969-2014. Data are taken from World Development Indicators, 2016 and BP Statistical Review of World Energy, 2016. The study uses CO_2 emission (mtoe), nuclear energy consumption (terawatt hours), oil consumption (tonnes) and coal consumption (mtoe) (Apergis & Payne 2010). Following Vidyarthi (2013), study uses absolute data rather than per capita data, as data in the form of per capita will only scale down the variables. Apart from these variables, trade openness (export + import as a percentage of GDP) is also used as additional variable (Ohlan 2015). The data are converted into natural logarithm.

The model: The following model is used to investigate the influence of nuclear energy consumption, oil consumption, coal consumption and trade openness on CO_2 emission:

$$LCO_t = f(LNC_t, LOC_t, LCC_t, LTO_t) \qquad ...(1)$$

Where, LCO is log of CO_2 emissions, LNC is log of nuclear energy consumption, LOC is log of oil consumption, LCC is log of coal consumption and LTO is log of trade openness.

Pesaran et al. (2001) established ARDL bounds testing approach to investigate the long run relationship among variables. Pesaran et al. (2001) suggested the F test for joint significance of the coefficient. The ARDL approach can be used without investigating the order of integration, but not applicable for I (2). Hence, Augmented Dickey Fuller test provided by Dickey & Fuller (1979) is used to check the stationarity of data. Furthermore, error correction model based on ARDL model is used to check the short run relationship among variables. The specification of ARDL model to find out the relationship between CO_2 emissions, nuclear energy consumption, oil consumption, coal consumption and trade openness is as follows:

$$\Delta LCO_t = \phi_0 + \sum_{i=1}^{\eta}\phi_1 \Delta LCO_{t-i} + \sum_{i=0}^{\eta}\phi_2 \Delta LNC_{t-i} + \sum_{i=0}^{\eta}\phi_3 \Delta LOC_{t-} + \sum_{i=0}^{\eta}\phi_4 \Delta LCC_{t-i} + \sum_{i=0}^{\eta}\phi_5 \Delta LTO_{t-i} + \alpha_1 LCO_{t-1} + \alpha_2 LNC_{t-1} + \alpha_3 LOC_{t-1} + \alpha_4 LCC_{t-1} + \alpha_5 LTO_{t-1} + \mu_t \qquad ...(2)$$

In the above equation (2), Δ is the operator of first-difference, L indicate natural logarithm, ϕ_0 is the intercept, t represents time, $\phi_1, \phi_2, \phi_3, \phi_4, \phi_5$ denotes the short-run dynamic relationship and $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ denote the long-run dynamic relationship. μ_t is the error term in the model. The null hypothesis H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$ of having non-existence of a long run relationship is tested against the alternate hypothesis H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq 0$ of co-integration. The standard form of error correction model (ECM) to find out short run relationship among the competing variables can be specified as follows:

$$\Delta LCO_t = \delta_0 + \sum_{i=1}^{k}\delta_1 \Delta LCO_{t-i} + \sum_{i=0}^{k}\delta_2 \Delta LNC_{t-i} + \sum_{i=0}^{k}\delta_3 \Delta LOC_{t-i} + \sum_{i=0}^{k}\delta_4 \Delta LCC_{t-i} + \sum_{i=0}^{k}\delta_5 \Delta LTO_{t-i} + \delta ECT_{t-i} + \mu_t \qquad ...(3)$$

ECT_{t-i} represents error correction term and δ is the coefficient of the error correction term which shows the speed of adjustment of the variables.

EMPIRICAL RESULTS AND DISCUSSION

Co-integration results: Before analysing the long run relationship among variables, it is necessary to check order of integration. Although, ARDL method does not require establishing the order of integration of the variables (unit-root test), yet it is necessary to check the stationarity of variables to confirm that variables are not I(2). This approach is appropriate regardless of whether the variables are I(0), and I(1). A prior analysis (using ADF test of unit root) of the competing variables indicates that the series were integrated of order 1, I(1). The computed F-statistic (5.47) of bound test is higher than upper (4.37) at 1% t level of significance, provides evidence of long run relationship among variables (Table 1). The implication of this result is that there exists a long run relationship among CO_2 emission, nuclear consumption, oil consumption, coal consumption and trade openness in India.

Long run elasticity using ARDL model: The long run elasticity of CO_2 emissions with respect to nuclear energy consumption, oil consumption, coal consumption and trade openness estimated using ARDL model are presented in Table 2. The empirical result explains that nuclear energy consumption has a statistically significant negative impact on CO_2 emissions in India. The magnitude of nuclear energy consumption (-0.016) implies that 1 percent increase in nuclear energy consumption will reduce the CO_2 emissions by 0.016 percent. It means that the use of nuclear energy will improve the environment in India (Baek 2016). Further, oil consumption and coal consumption are statistically significant and have positive effect on CO_2 emissions. It further implies that 1 percent increase in oil consumption will increase the CO_2 emissions by 0.20 percent, while 1 percent rise in coal consumption will increase the CO_2 emissions by 0.63 percent. These results are consistent with the findings of Baek (2016). This is an alarming signal and a serious threat for India if energy consumption from non-renewable energy sources will continue in the same pace. Therefore, there is an urgent need to shift from non-renewable energy resources to carbon free fuel (nuclear and renewable energy) to further minimize CO_2 emissions. In addition, the long-run elasticity estimate of CO_2 emissions with respect to trade openness is positive at 5 percent level of significance and the magnitude of 0.14 indicate that 1 percent increase in trade openness will increase the CO_2 emissions by 0.14 percent. This implies that trade liberalization and export of manufacturing products results in more energy consumption that leads to increase in CO_2 emissions.

Table 1: ARDL Bounds test for Co-Integration.

F statistics	5.4715* Critical Values	
Significant level	Lower bound, I(0)	Upper bound I(1)
1%	3.29	4.37
5%	2.56	3.49
10%	2.2	3.09

Note: *indicates significant at 5 percent level

Table 2: ARDL model long run coefficients estimates.

Variables	Coefficient	Standard Error	T-Ratio[Prob.]
LNC	-0.0161*	0.0069	-2.3141[0.0266]
LOC	0.2092*	0.0495	4.2303[0.0002]
LCC	0.6359*	0.0451	14.0891[0.000]
LTO	0.1427*	0.0496	2.8749[0.0068]
Constant	0.6759*	0.2259	2.9973[0.0051]

Note: *Indicates significant at 5 percent level, Prob. represents probability

Table 3: Diagnostic test of ARDL test.

Diagnostics test	Statistics (prob.)
R^2	0.9999
Adjusted R^2	0.9987
Breush -Godfrey LM	0.4152
Durbin Watson	2.0372
Hetroskedasticity test	0.0625

Source: Authors' own calculations

The diagnostic test results validate the non-existence of serial correlation and hetroskedasticity in the estimated ARDL model. Hence, the model has passed all diagnostic tests (see Table 3). The model is reasonably good fit, as reflected by high R^2 value i.e., 99 percent. Furthermore, CUSUM and CUSUM square test also applied, that confirms the stability of the model over the sample period.

Short run elasticity based on ECM: Now coming to short run analysis, the results of error correction model for the underlying ARDL model are presented in Table 4. The empirical results indicate that nuclear energy consumption has negatively associated with CO_2 emissions in shorn run. This implies that nuclear energy reduces CO_2 emissions in India. Contrary to this, oil consumption, coal consumption and trade openness have positive and significant relationship with CO_2 emissions in India. These results confirm the empirical evidence that dirty energy mix is a key factor affecting CO_2 emissions in India. The coefficient of lagged ECT term is found negative and significant at five percent level, which shows that any deviation from long run equilibrium between variables will be corrected with the speed

Table 4: Results of error correction represents of ARDL model.

Variables	Coefficient	Standard Error	T-Ratio[Prob.]
ΔLNC	-0.0133*	0.0059	-2.247[0.0003]
ΔLOC	0.0175*	0.0506	3.475[0.0013]
ΔLCC	0.5938*	0.0421	14.13[0.0000]
ΔLTO	0.1497*	0.0422	3.5331[0.0017]
ECT_{t-1}	-0.4581*	0.1867	-2.4526[0.0013]
Diagnostic test	R^2=0.895	F- stat=65.31[0.0000]	DW- statistics= 2.031

Note: *Indicates significant at 5 percent level, Prob. represents probability; Source: Authors' own calculations

of 45 percent every year. The findings imply that continuous increase in energy consumption to meet the requirement of rapid growth may result in more environmental degradation at global level in coming years.

CONCLUSIONS AND POLICY IMPLICATIONS

The aim of this study is to examine the long run and short run impact of nuclear energy consumption on environment by including coal consumption, oil consumption and trade openness as an additional variable in India over the time period of 1969-2013. The new contribution of this paper is to access the short run and long run effects of nuclear and non-renewable energy sources on CO_2 emissions in India by simultaneously applying an ARDL co-integration approach. The empirical results reveal the long run relationship among CO_2 emissions, nuclear energy consumption, coal consumption and trade openness. The results of long run ARDL model indicate that nuclear energy consumption reduces CO_2 emissions in India. However, non-renewable energy sources increases CO_2 emissions in India. In addition, trade openness is also found positively related with CO_2 emissions and indicates that trade liberalisation will lead to speedy growth of pollution-intensive industries in India.

The results confirm that energy consumption, especially through oil and coal consumption, is an important determinant affecting CO_2 emissions in India and should be controlled. There is an urgent need for policy development towards increasing energy efficiency. Nuclear power will supply electricity at lower cost in comparison of coal and also reduce dependence on import of oil and petroleum products. This will improve current account balance and boost the economic growth in long run. Further, to increase the capacity of nuclear power stations, government should increase the investment in nuclear and carbon free energy sources like wind and solar energy to reduce long run consequences of carbon emissions for faster and sustainable growth.

REFERENCES

Alam, M.M., Murad, M.W., Noman, A.H.M. and Ozturk, I. 2016. Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing environmental Kuznets curve hypothesis for Brazil, China, India and Indonesia. Ecological Indicators, 70: 466-479.

Al-Mulali, U. 2014. Investigating the impact of nuclear energy consumption on GDP growth and CO_2 emission: A panel data analysis. Progress in Nuclear Energy, 73: 172-178.

Apergis, N. and Payne, J.E. 2009. Energy consumption and economic growth in central America: Evidence from a panel cointegration and error correction model. Energy Economics, 31(2): 211-216.

Apergis, N. and Payne, J.E. 2010. A panel study of nuclear energy consumption and economic growth. Energy Economics, 32(3): 545-549.

Baek, J. 2016. Do nuclear and renewable energy improve the environment? Empirical evidence from the United States. Ecological Indicators, 66: 352-356.

BP Statistical Review of World Energy 2016. Statistical Review of World Energy, London.

Farhani, S., Chaibi, A. and Rault, C. 2014. A study of CO_2 emissions, output, energy consumption and trade. IPAG Business School Working Paper 056.

Dickey, D.A. and Fuller, W.A. 1979. Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74(366): 427-431.

Gökmenoglu, K. and Taspinar, N. 2016. The relationship between CO_2 emissions, energy consumption, economic growth and FDI: The case of Turkey. The Journal of International Trade & Economic Development, 25(5): 706-723.

GOI 2015. Department of Atomic Energy. Government of India, India.

Heo, J.Y., Yoo, S.H. and Kwak, S.J. 2011. The causal relationship between nuclear energy consumption and economic growth in India. Energy Sources, Part B: Economics, Planning, and Policy, 6(2): 111-117.

Jalil, A. and Mahmud, S.F. 2009. Environment Kuznets curve for CO_2 emissions: A cointegration analysis for China. Energy Policy, 37(12): 5167-5172.

Lee, C.C. and Chiu, Y.B. 2011. Nuclear energy consumption, oil prices, and economic growth: Evidence from highly industrialized countries. Energy Economics, 33(2): 236-248.

Lee, S.J. and Yoo, S.H. 2016. Energy consumption, CO_2 emission, and economic growth: Evidence from Mexico. Energy Sources, Part B: Economics, Planning and Policy, 11(8): 711-717.

Lin, H.P., Yeh, L.T., Tsui, H.C. and Chien, S.C. 2014. Nuclear and non-nuclear energy consumption and economic growth in Taiwan. Energy Sources, Part B: Economics, Planning, and Policy, 10(1): 59-66.

Menyah, K. and Wolde-Rufael, Y. 2010. CO_2 Emissions, nuclear energy, renewable energy and economic growth in the US. Energy Policy, 38(6): 2911-2915.

Ohlan, R. 2015. The impact of population density, energy consumption, economic growth and trade openness on CO_2 emissions in India. Natural Hazards, 79(2): 1409-1428.

Ohlan, R. 2016. Renewable and non-renewable energy consumption and economic growth in India. Energy Sources, Part B: Economics, Planning and Policy, 11(11): 1050-1054.

Ozturk, I. and Uddin, G.S. 2012. Causality among carbon emissions, energy consumption and growth in India. Ekonomska Istrazivanja/Economic Research, 25(3): 752-775.

Peng, H., Tan, X., Li, Y. and Hu, L. 2016. Economic growth, foreign direct investment and CO_2 emissions in China: A panel Granger causality analysis. Sustainability, 8(233): 1-13.

Pesaran, M.H., Shin,Y. and Smith, R.J. 2001. Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16(3): 289-326.

Saboori, B. and Sulaiman, J. 2013. CO_2 emissions, energy consumption and economic growth in association of Southeast Asian Nations (ASEAN) countries: A cointegration approach. Energy, 55: 813-822.

Saboori, B., Sulaiman, J.B. and Mohd, S. 2012. An empirical analysis of the environmental Kuznets curve for CO_2 emissions in Indonesia: The role of energy consumption and foreign trade. International Journal of Economics and Finance, 4(2): 243-251.

Saidi, K. and Hammami, S. 2015. The impact of CO_2 emissions and economic growth on energy consumption in 58 countries. Energy Reports, 1: 62-70.

Vidyarthi, H. 2013. Energy consumption, carbon emissions and economic growth in India. World Journal of Science, Technology and Sustainable Development, 10: 278-287.

Wolde-Rufael, Y. 2010. Bounds test approach to cointegration and causality between nuclear energy consumption and economic growth in India. Energy Policy, 38(1): 52-58.

Wolde-Rufael, Y. and Menyah, K. 2010. Nuclear energy consumption and economic growth in nine developed countries. Energy Economics, 32(3): 550-556.

World Development Indicators 2016. World Development Indicators. The World Bank.