Analysis of renewable and nonrenewable energy consumption, real GDP and CO2 emissions: A structural VAR approach in Romania

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Abstract:
Impulse responses of our structural VAR portray a positive correlation between the real GDP of Romania and energy consumption. The present study employs the annual data covering the period 1980-2008, and brings to light the factors playing important role in satisfying the energy requirements, its economic and social implications. Any short-run rise in energy requirements is contented with the help of nonrenewable energy consumption, for renewable energy is not so common in Romania. In addition, high installation cost and the ignorance about our environmental responsibilities etc. might be other possible factors for this limited use of renewable energy. It also identifies a strong positive correlation between the nonrenewable energy consumption and the CO_2 emissions; resultantly, CO_2 piles on in the ecosystem as the nonrenewable energy consumption boosts up. This exaggeration of the CO_2 emissions ever time paves some way for the renewable energy which appears to play a minor role at this stage. Impulse responses represent some weak substitution between the nonrenewable energy consumption with the renewable energy consumption, which lowers carbon emissions and communicates some positive message.

1. Introduction

The negotiation of the Kyoto Protocol (1997) was the first event when importance of clean and sustainable environment was recognized by both developing and developed countries. According to this protocol, the Greenhouse gas emissions (GHGs) should be reduced by 5.2 % from the level of the 1990 during 2008-2012. Further, protocol considers GHGs, particularly carbon dioxide (CO_2) emissions, as the main causes of global warming. Halicioglu (2009) also mentioned that CO_2 emissions are the most notorious polluting gas and it is responsible for 58.8% of the GHGs worldwide. However, it was unable to resolve the environmental issues in an appropriate manner and came up with a judgmental and adequate roadmap (Sathaye et al., 2006). Nevertheless, protocol accepted renewable energy sources (RES) as one of the key solutions to climate change and the increasing energy demand.

The increasing threat of global warming, consecration of GHGs in the atmosphere, and climate change have attracted attention of researchers in mitigating its affect and finding alternative ways to fulfill rapidly growing energy demand. Interestingly, Global warming depends on worldwide GHGs emissions; however, its consequences differ among countries, based on the latter's' social and natural characteristics. Stern et al. (2006) emphasize that the radical change in temperatures would affect all economies disregarding the nature of the economy. However, the worst effect will be realized by the poorest and populous nations, of course they are not main culprit. Of course, the path through which consumption of RES brings higher and higher growth is uncertain i.e., there is no unique way to say that this is the way through which RES can boost economic growth" (Tiwari 2011a).

Nonetheless, a few studies have attempted to provide a plausible mechanism for such case. For example, Domac et al. (2005) and Chien and Hu (2007) suggest that renewable energy might increase the macroeconomic efficiency and hence boost economic growth. This either might be due to the expansion of business and new employment opportunities brought by renewable energy industries or through the import substitution of energy, which has direct and indirect effects on the increase of an economy's GDP and/or trade balance. Similarly, Masui et al. (2006) suggested that the issues related to the climate change can be addressed by, for example, adopting environmentally sustainable technologies, improving energy efficiency, forest conservation, reforestation, water conservation, or energy saving. The promotion of renewable energy sources is another well-accepted solution to the mitigation of CO_2 emissions. Krewitt et al. (2007) suggest that renewable energy sources could provide as much as half of the world's energy needs by 2050 in a target-oriented scenario to prevent any dangerous anthropogenic interference with the climate system. Abulfotuh (2007) suggests that one possible solution to the environmental risks brought by the escalating demand for energy is to consider immediate change in the composition of an energy resource portfolio. It is expected that renewable energy sources have great potential to solve a major part of global energy sustainability.

II. Romanian Context

If we see the situation of Romania in the present context, we find evidence of a strong positive correlation between the nonrenewable energy resource and the CO_2 emissions. The increase in the nonrenewable energy consumption augments the environment with intensified CO_2. The growth in the nonrenewable energy consumption was at its lowest point in the year 1990; it got the knoll in year 2000. There was continuous growth in the nonrenewable energy in 2000s on average, while with a little drop in year 2004, see Figure-1. Similar is the case with real GDP, increase in the real GDP encourages the use of nonrenewable energy consumption. Non-availability of the renewable energy resources, their costly installation, or the ignorance among the masses about its practical application might be the possible factors responsible for this. Real GDP experienced first lowest growth rate in the year 1991, and second in year 1997. Each decline in real GDP was also associated to downfall in the nonrenewable energy resources, see Figure-2.

There is significant evidence of the negative correlation between the nonrenewable and the renewable energy consumption in the Romanian economy. Substitution of the nonrenewable energy consumption with the renewable energy consumption communicates a positive message. It portrays the effort being undertaken by the Romania to clean the environment. Nonetheless, these efforts were not sustainable just for the year 1989, see Figure-3.

Figure-1

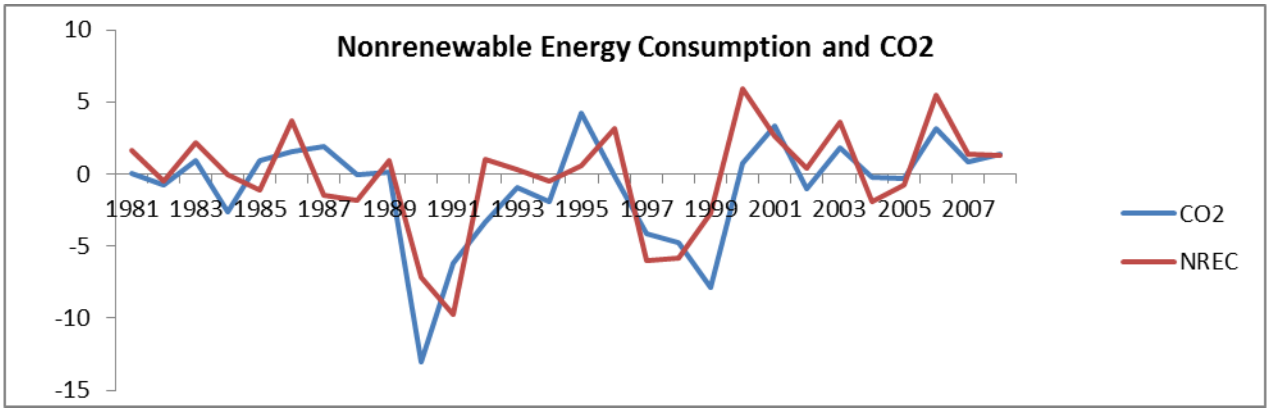


Figure-2

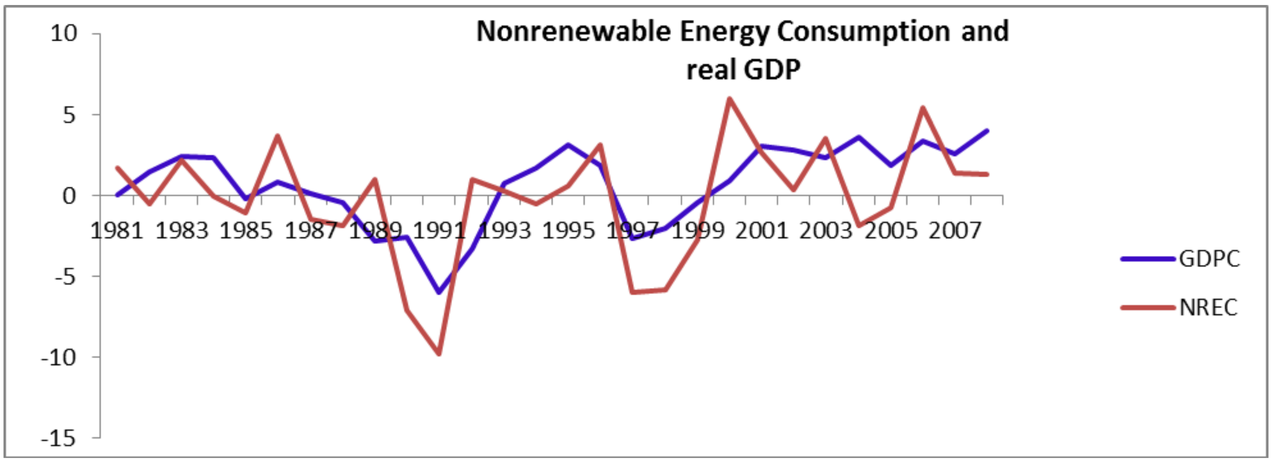
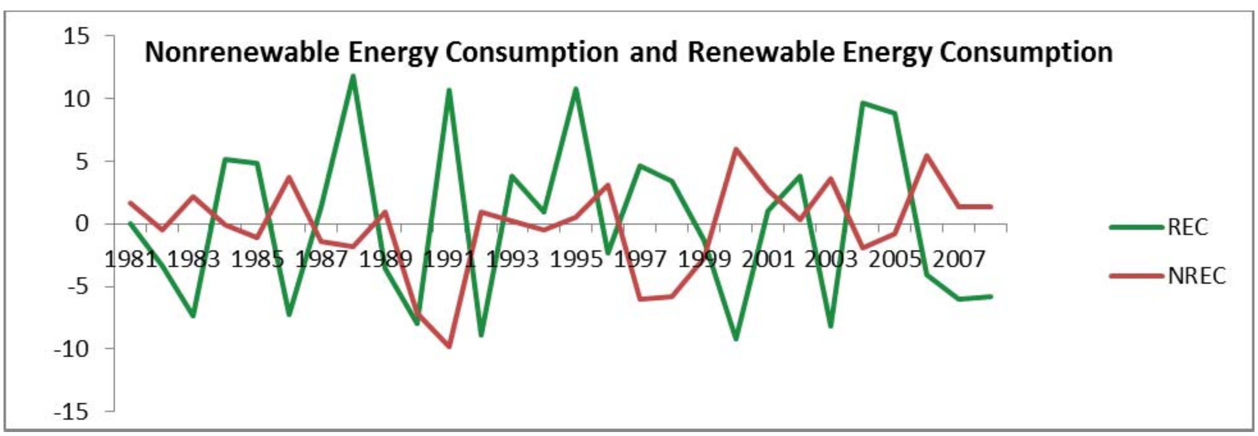


Figure-3



Analysis of the relationship between the renewable energy consumption and the CO_2 emissions asserts the stable relationship. A rise in the renewable energy consumption was followed by lower carbon emissions, but it was just up to the year 1996. The subsequent period was subject to the unstable relationship; both the renewable energy consumption and CO_2 were mounting. This situation continued till the year 2002, afterwards there seemed some positive substitution between the renewable energy and the CO_2 emissions. In addition, it remained much volatile through the analysis. Nonetheless, not much serious efforts appear to be undertaken to sustain the consumption and growth in renewable energy, as the Figure-4 portrays it.

Until 1981 to 1990, there seems no relationship between the renewable energy and the real GDP; however, the subsequent period of 1992 to 1996 portrays some stable relationship between the renewable energy and the real GDP. Both were positive in this period, but later on there was unstable relationship between the real GDP and the renewable energy. Thus, it can be concluded that all the project working on the renewable energy inputs were not based on permanent foundation. The temporary encampment of the renewable energy utilization resulted in the higher level of volatility in it, see Figure-5.

Figure-4

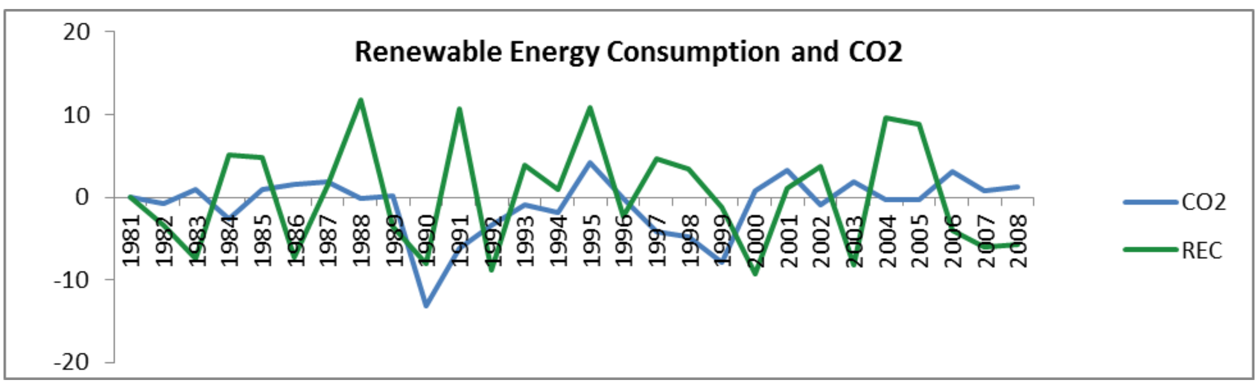
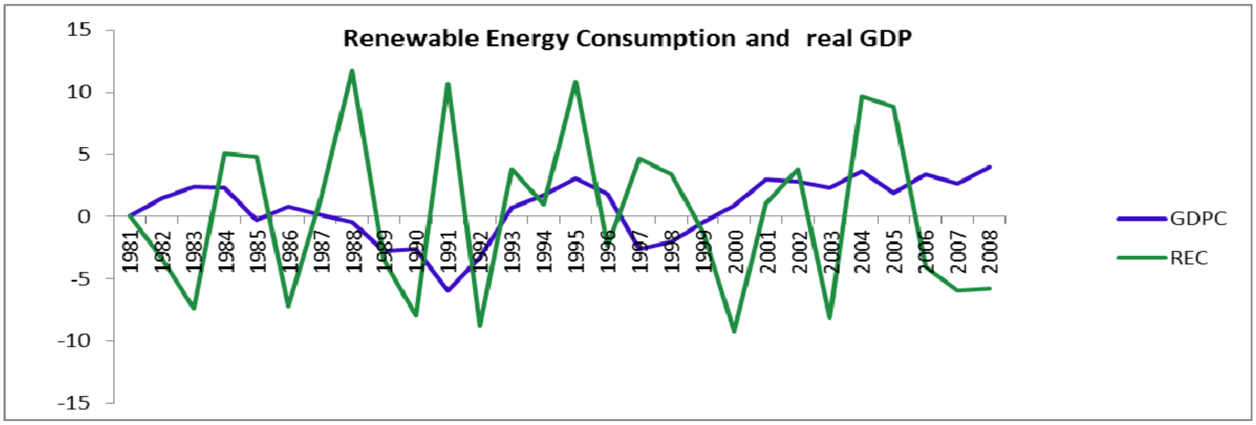


Figure-5



III. A brief review of literature

There are various studies analyzing the dynamics of the relationship between electricity consumption or energy consumption and economic growth either in the bivariate or multivariate framework. However, literature in the field of renewable energy consumption (in disaggregated framework) is relatively less. In this section, we limit ourselves to present a brief review on the recent available literature in the field of renewable energy consumption or disaggregated energy consumption and economic growth.[1] Based on the findings we can classify studies into four groups.

The first group comprises of studies that find unidirectional causality running from energy consumption (both aggregate and disaggregate level) to GDP. Yang (2000) found unidirectional causality running from natural gas to GDP for Taiwan. Wolde-Rufael (2004) found unidirectional Granger causality from coal, coke, electricity, and total energy consumption to real GDP. Sari and Soytas (2004) found that waste had the largest initial impact, followed by oil on real GDP. However, lignite, waste, oil, and hydropower explained the larger amount of GDP variation among energy sources within the 3-year horizon respectively. Awerbuch and Sauter (2006) found that RES had a positive effect on economic growth by reducing the negative effects of oil prices volatility either by providing energy supply security or otherwise. Ewing et al. (2007) found that shocks arise due to NRES consumption like coal, gas and oil had more impact

[1] Comprehensive review of literature on the relationship between energy consumption/electricity consumption and economic growth/employment is available in Tiwari (20011b, 2011c and 2011d) and references therein one may refer that.

on output variation than the shocks arise due to RES. Chien and Hu (2008) have studied the effects of RES on GDP for 116 economies in 2003 through the Structural Equation Modeling (SEM) approach. They concluded that RES had a positive indirect effect on GDP through the increase in capital formation. Lotfalipour et al. (2010) investigated the causal relationships between economic growth, carbon emission, and fossil fuels consumption, using the Toda-Yamamoto method for Iran during the period 1967-2007. They found that gas consumption lead to economic growth. Shahbaz et al. (2010) investigated relationship between CO_2 emissions, energy consumption and economic growth in case of Pakistan and concluded that economic growth and energy consumption have positive impact on CO_2 emissions. In a very recent study on India, Tiwari (2011e) used SVAR approach and showed that a positive shock on the consumption of RES increased GDP and decreased CO_2 emissions and a positive shock on GDP had a very high positive impact on the CO_2 emissions. Hence, he provides evidence to support the hypothesis that consumption of RES increases the economic growth of India. Tiwari (2011a) analyzed the relative performance of RES and NRES on economic growth in European and Eurasian countries in a panel framework by using a Panel Vector Autoregressive (PVAR) approach for the period 1965-2009. He finds that the impact of RES, in general, positive on the growth rate of GDP. Further, he found that growth rate of NRES has negative impact on the growth rate of GDP and increase CO_2 emissions.

Second are the studies that find a unidirectional causality running from economic growth to energy consumption. This group also includes those studies that found that economic growth/GDP has significant positive impact on the energy consumption. Yang (2000) found unidirectional causality running from GDP to oil consumption for Taiwan. Sari et al. (2008) by using autoregressive distributed lag (ARDL) approach for the USA found that, in the long-run, industrial production and employment were the key determinants of fossil fuel, hydro, solar, waste and wind energy consumption, but did not have a significant impact on natural gas and wood energy consumption. Sadorsky (2009a) used a panel data model to estimate the impact of RES (which includes geothermal, wind and solar power, waste and wood) on economic growth and CO_2 emissions per capita and oil price for the G7 countries. The author found that, in the long run, real GDP per capita and CO_2 emissions per capita were the main drivers of renewable energy consumption per capita. Oil prices had a smaller and negative effect on renewable energy consumption. In the short term, movements drove variations in renewable energy consumption back to the long-term equilibrium rather than short term shocks. Sadorsky, (2009b) studied the relationship between RES (wind, solar and geothermal power, wood and wastes) and economic growth in a panel framework of 18 emerging economies for the period 1994-2003 and found that increases in real GDP had a positive and statistically significant effect on renewable energy consumption per capita.

Third are the studies that find bidirectional causality. Yang (2000) found bidirectional causality between aggregate energy consumption and GDP in Taiwan. Further, at the disaggregation of energy sources he found bidirectional causality between GDP and coal, GDP and electricity consumption and GDP and total energy consumption. Apergis and Payne (2010) attempted to study the relationship between RES and economic growth for 20 OECD countries over the period 1985-2005, within a framework of production function by incorporating capital formation and labor in the analysis and found a long-run equilibrium relationship between real GDP, RES, real gross fixed capital formation, and the labor force. Further, their results of Granger-causality indicate bidirectional causality between RES and economic growth in both the short- and long-run.

The fourth group comprises studies that find no causal linkages between energy consumption (at aggregate or disaggregate level) and economic growth. Wolde-Rufael (2004) found no evidence of causality in any direction, between oil and real GDP. Payne (2009) provided a comparative causal analysis of the relationship between RES and NRES and real GDP for the USA over the period 1949-2006 and found no Granger causality between renewable and nonrenewable energy consumption and real GDP. Menegaki (2011) examined the causal relationship between economic growth and renewable energy for 27 European countries in a multivariate panel framework over the period 1997–2007 using a random effect model and including final energy consumption, greenhouse gas emissions and employment as additional independent variables in the model. The author found no evidence of causality between renewable energy consumption and GDP. Lotfalipour et al. (2010) found that carbon emissions, petroleum products, and total fossil fuels consumption did not lead to economic growth.

IV. Econometric Framework

Econometric literature has specified the significance of the structural estimates over the reduced form estimates. The structural estimates provide the interpretation that can be used for inferential analysis. Fortunately, the contemporaneous econometric techniques have enabled us to identify the structural estimates of the model. Structural Vector Autoregression (SVAR) is considered best in this regard. It is a flexible framework to identify the structural behavior of the economy; it borrows the identification scheme after observing the nature of data.

$$BX_t = \eta_0 + \eta_1 X_{t-1} + \varepsilon_t \qquad (1)$$

Where X_t is a vector of all the relevant series; $X_t = [NREC_t, REC, GDPC_t, CO_{2t}]$.

$NREC_t$ is the growth rate of nonrenewable energy consumption, REC_t is the growth rate of renewable energy consumption, $GDPC_t$ is the growth rate of real GDP and CO_{2t} represents growth rate of the CO_2 emissions. X_{t-1} is the matrix of all the series in the lagged form. B is also a matrix that denotes the coefficients having the contemporaneous relationship with the series. η_0 denotes the vector with the intercept terms, and η_1 represents the coefficient matrix of lagged series. ε_t stands for the vector of the innovations, that are white noised in nature.

$$X_t = \lambda_0 + \lambda_1 X_{t-1} + e_t \qquad (2)$$

Where: $\lambda_0 = B^{-1}\eta_0$

$\lambda_1 = B^{-1}\eta_1$

$e_0 = B^{-1}\varepsilon_t$

and

$E(e_{it}) = 0 \quad ; \quad (i = 1,2,....n)$

$E(e_{it})^2 = \delta^2$

$E(e_{1t}, e_{1t-1}) = E(e_{2t}, e_{kt-1}) = 0$

$E(e_{1t}, e_{2t})$ not necessarily zero.

Equation-2 is the VAR in reduced form rather than the structural VAR. Ordinary Least Square (OLS) technique can be applied to estimate it, for there are the identical independent series on the right hand side of the equation. Any dissimilar composition will necessitate the seemingly unrelated (SUR) framework. It provides the best results in case the variables do not have the same right hand side composition (Enders, 2004).

Identification of the System:

$\left[\frac{n^2-n}{2}\right]$ restrictions are required to obtain the structural VAR from the reduced form VAR. Share of the nonrenewable energy consumption in the production has significant macroeconomic implications. Higher is the nonrenewable energy consumption, more will be the CO_2 emission in the environment. This encourages the society to the use of renewable energy consumption. The renewable energy, such as the hydro systems, comprises the storage arrangements. It affects the real GDP and causes to reduce the CO_2 emission indirectly (Amundsen and Bergman, 2002). These two findings place the reasonable restrictions on the system for the identification of SVAR. In addition, the same set of restrictions can be achieved in the recursive VAR if one uses the ordering specified in the Econometric Framework of our SVAR.

V. Data analysis and results

The analysis period of present study is 1980-2008, and all the variables in level form are denoted as: nonrenewable energy consumption ($NREC_t$), renewable energy consumption (REC_t), real GDP (GDP_t) and CO_2 emission (CO_{2t}). The data of all the variables has been collected from world development indicators (CD-ROM, 2011). We used ADF unit root by Dickey and Fuller (1979) to test stationarity properties of the variables. The information about integrating order of the variables is necessary to ensure that none of variable is stationary at 2nd difference. Although ARDL bounds testing approach to cointegration is flexible about stationarity properties of the variables i.e. autoregressive distributive lag model (ARDL) is applicable if the variables are I(1) or I(0) or I(1)/I(0)[2]. The assumption of ARDL bounds testing approach is that the variables should be integrated at I(1) or I(0). We cannot apply ARDL bounds testing approach to cointegration to examine long run relationship among the variables if any variable does stationary at I(2) or beyond. Furthermore, ARDL bounds testing approach to cointegration is much better for small sample data set (Narayan and Smyth, 2004). The traditional norms specify to use the Ordinary Least Technique (OLS) if all the variables are stationary. It is a good technique to draw the econometric inferences, but it is too much formal and is also subject to Lucas critique. The reduced form parameters remain the same if one conducts the simulations. Structural Vector Auto-regression framework (SVAR) overcomes this deficiency effectively. It not only avoids the Lucas critique but also provide a general platform to analyze the co-movement among the variables, regardless of the issue of endogeneity. Beginning with unit root test, the results of ADF unit root test are reported in Table-1 revealing that all variables have unit root problem at their level form and found stationary at their 1st differenced form. The unique level of integration of the variables tends to apply ARDL bounds testing approach to cointegration to test long run relationship between the variables.

Table-1: Unit Root Analysis

Variables	ADF Test at Level		ADF Test at 1st Difference	
	T-statistic	Prob-value	T-statistic	Prob-value
CO_{2t}	-1.8715	0.6412	-3.5193	0.0573
GDP_t	-1.1797	0.8947	-3.3636	0.0849
REC_t	-2.7925	0.2121	-5.1422	0.0017
$NREC_t$	-1.3986	0.8283	-3.8275	0.0289

To apply ARDL bounds testing, it is necessary to select appropriate lag order of the variables to be used in model. In doing so, we used Akaike information criterion (AIC) to choose appropriate lag length. The empirical evidence noted in Table-2 reveals that our calculated F-statistic does not cross lower critical bound which leads to accept hypothesis of no cointegration. We used

[2] The theoretical back ground of the ARDL bounds testing approach to cointegration can be accessed from Pesaran et al. (2001).

critical bounds generated by Narayan (2005) which are considered more suitable for small sample[3]. This implies that there is no long run relationship is found between renewable and nonrenewable energy consumption, real GDP and CO_2 emissions for period of 1980-2008 in case of Romania.

Table-2: Bounds Testing Analysis

Model	$F_{CO_2}(CO_2/GDP,REC,NREC)$	
Optimal Lag	(1, 1, 1, 0)	
F-Statistics	2.109	
	Critical values (T = 29)	
	Lower bounds $I(0)$	Upper bounds $I(1)$
1 per cent level	10.605	11.650
5 per cent level	7.360	8.365
10 per cent level	6.010	6.780
Diagnostic tests	Statistics	
R^2	0.8885	
Adjusted-R^2	0.7856	
CUSUM	Stable	
CUSUMsq	Stable	
Note: The optimal lag structure is determined by AIC.		

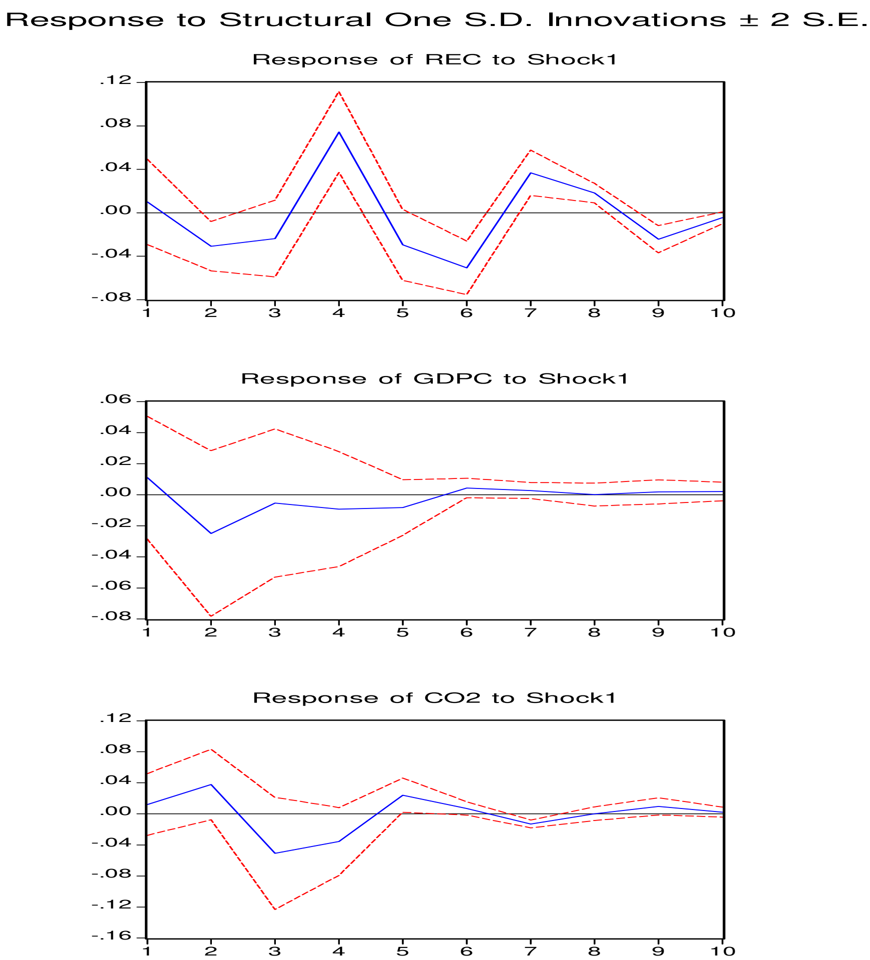
It is evident that all series are integrated of the same order, but there is no Cointegrating relationship among them. The second best way to proceed is making the data stationary, so differencing is required to the data applicable. Just differencing the date has no economic meanings, so we get the growth rates of all the series. Two benefits are associated with this scheme, first growth form renders some economic understanding and second the data is fit for the use in the SVAR. Next step is to interpret the results of impulse responses of the growth rates of nonrenewable energy consumption (NREC), renewable energy consumption (REC), real GDP (GDP) and the CO_2 emission (CO_2). It portrays the response of a variable up to 10 period time horizons, in response to a one standard deviation shock. Dotted red lines indicate the 2 standard deviation error bands.

Figure-1 portrays the impulse responses of the various series in response to a one standard deviation shock to nonrenewable energy consumption. It results in higher CO_2 emission in the environments, it prolongs up to the first two periods. It also results in the drop of renewable

[3] See for more details (Shahbaz et al. 2011)

energy. The subsequent period experiences the reverse situation; fall in the CO_2 emission along with the rising consumption of the renewable energy. In addition, each rise of CO_2 emission is followed by the escalation in the renewable energy consumption, and again drop in the CO_2 emission. This indicates Romania gives due attention to the rising level of the CO_2 emission in the environment, and adopts the preventive measures immediately. This shock also causes to fall in the real GDP but it is insignificant.

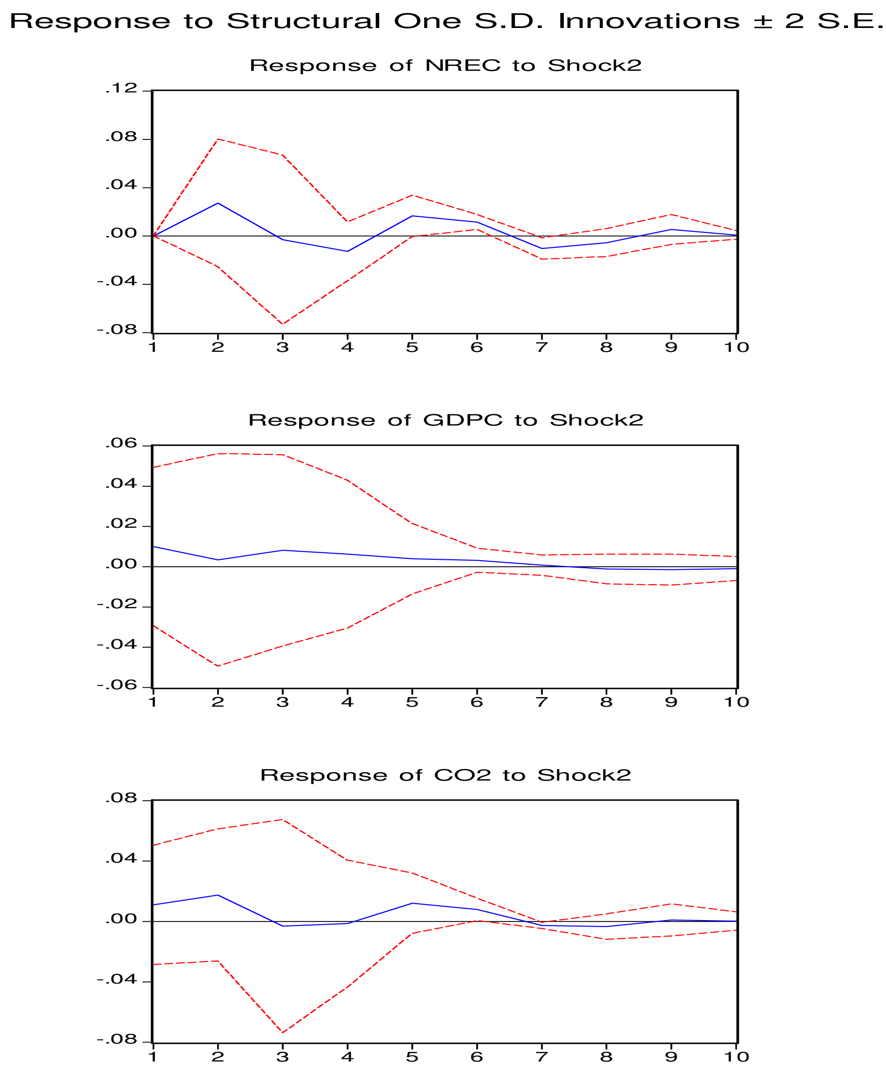
Figure-1 Shock to Nonrenewable Energy Consumption (NREC)



The impulse response function is based on 10 period time horizons.
Dotted red lines indicate the 2 standard deviations error bands.

Figure-2 portrays the impulse responses of the series in the system in response to a one standard deviation shock to renewable energy consumption. It lowers the variable cost of production, and prices fall. It improves the real income of the consumers, aggregate demand augments and the economy flourishes. These positive economic movements upshot in the higher consumption, more goods are required to satisfy this increase in the aggregate demand. At the same time, more energy is required to smooth the supply of goods, and to cater this new demand. Businessmen acquire the instruments and machines that can be used in the short-run to satisfy this rise in demand. Nonrenewable energy is the main source of energy used in the conventional production appliances. Although the rise in the nonrenewable energy consumption also paves the way for the higher CO_2 emissions, but this channel indicates, this rise is insignificant.

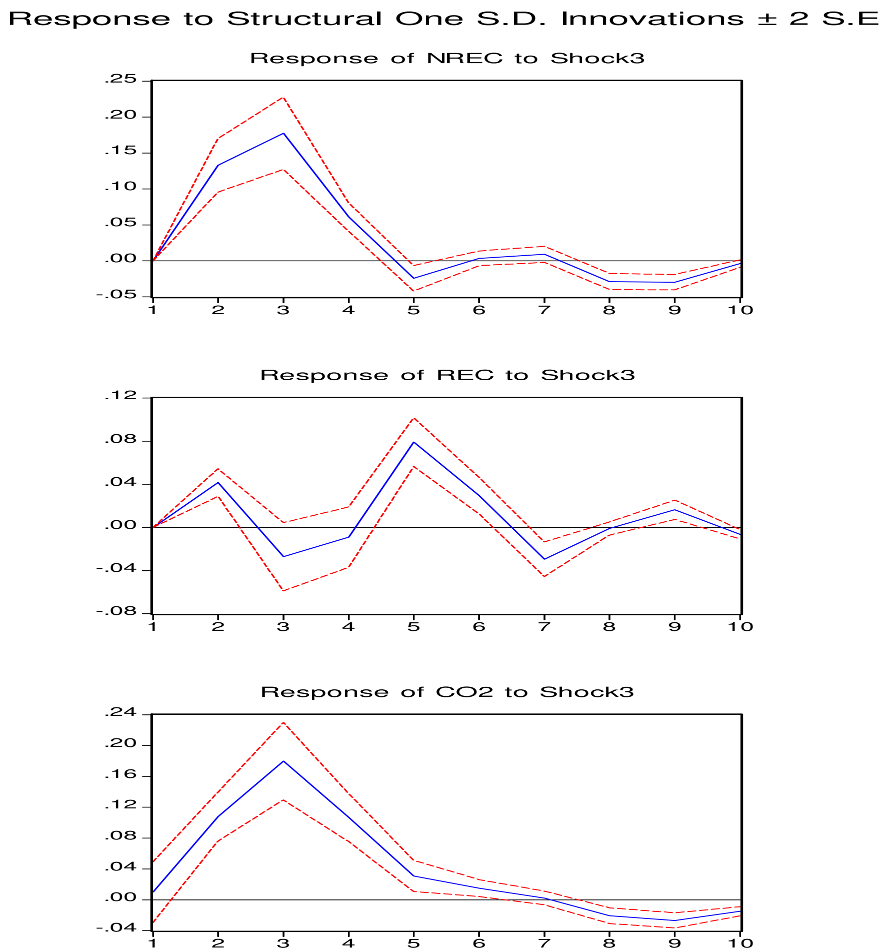
Figure-2 Shock to Renewable Energy Consumption (REC)



The impulse response function is based on 10 period time horizons.
Dotted red lines indicate the 2 standard deviations error bands.

Figure-3 portrays the impulse responses of the relevant series in response to a one standard deviation shock to the real GDP. It increases both the nonrenewable and the renewable energy consumption, but the increase in the nonrenewable energy consumption is higher than the renewable energy consumption. This finding is consistent with the previous paragraph that the businessmen increase the use of the nonrenewable energy in the short-run to smooth the supplies of goods. This rise in energy requirement gives birth to the higher level of CO_2 emissions. Moreover, there is also significant evidence of the fall of CO_2 emissions due to the decrease in the nonrenewable energy consumption.

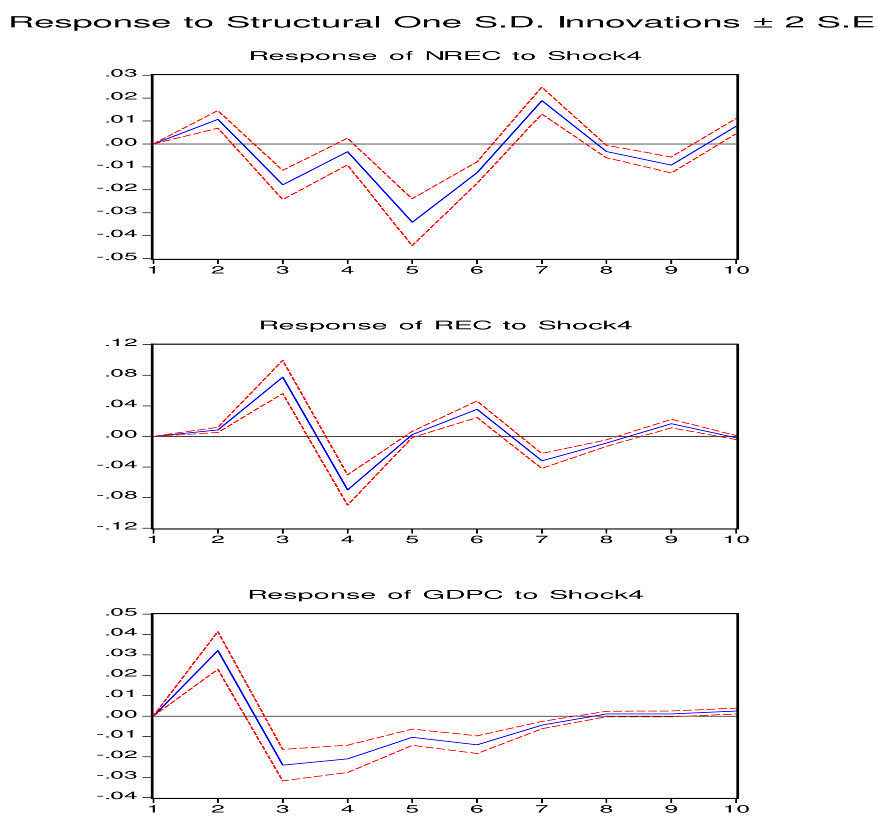
Figure-3 Shock to Real GDP (GDPC)



The impulse response function is based on 10 period time horizons.
Dotted red lines indicate the 2 standard deviations error bands.

Finally Figure-4 portrays the impulse responses to a one standard deviation shock to the CO_2 emissions. It raises both the nonrenewable and the renewable energy consumption, but the rise in the renewable energy consumption is higher as compared to the nonrenewable energy consumption. This rise in energy consumption also boosts the economic activity, real GDP boosts up. All these specify that the stabilization process starts after one year, the renewable energy consumption increase and the nonrenewable energy consumption decrease. This fall in the nonrenewable energy consumption results in the economic catastrophe in short-run, showing the heavy dependence of the Romania on the nonrenewable energy. Hence, it can be concluded that Romania should not attempt to truck its energy composition in some hasty way; rather it should be accomplished in some smooth transitions, lowering the economic loss occurring out of it.

Figure-4 Shock to CO_2 Emissions (CO_2)



The impulse response function is based on 10 period time horizons.
Dotted red lines indicate the 2 standard deviations error bands.

Decomposing the Variance of the series reveals real GDP is responsible for most of the variation in the nonrenewable energy consumption i.e. 69.8%. It is more than double as compared to the variation in renewable energy consumption, consistent with our prior findings. The second most variation in the nonrenewable energy consumption comes through the nonrenewable energy consumption itself. The variation in the renewable energy consumption comes about equally from all the shocks. Finally, it reveals renewable energy consumption contributes the least in the variation of the CO_2 emissions; see Table 4, 5 and 6 in Appendix.

VI. Conclusion and Policy implications

There is sufficient evidence of the positive correlation among the real GDP, nonrenewable energy consumption and the CO_2 emissions in Romania. An economic uplift moves the aggregate demand up, and the energy requirements in the manufacturing sector gets bigger. This short-term rise in the economic activity is supported by the nonrenewable energy consumption. Manufacturers use it, because it is the fastest source of energy in the shout-run. It makes their supplies smooth and they make higher profits out of this rising level of aggregate demand. This free market mechanism motivated by the profit motives brings severe losses to the society. It pollutes the environment with the rising CO_2 emissions. It is the worst externality out of the use of nonrenewable energy consumption, and also intensifying the issue of the global warming.

Renewable energy serves the society in a better way, and is the demand of the era. It minimizes the negative externality, CO_2 emissions, arising out of the production practices prevailing in Romania. Initially, it can be exercised to overcome the new energy requirements of the production; moreover, it can be substituted completely with the nonrenewable energy in the long-run. However, the ground realities differ in this regard. Presently, renewable energy consumption comprises very little share in the total energy requirements. Higher time and installation cost, no-availability of this source of energy and ignorance about its damaging impact might be the hurdles that prevent its use.

The impulse responses reveal that CO_2 emissions rises significantly if the production is being facilitated by the use of nonrenewable energy consumption, while it remain insignificant if the production is being facilitated by the renewable energy consumption. This rising level of CO_2 emissions, out of the use of nonrenewable energy consumption, results in the environmental degradation. When the CO_2 emissions reach some higher level, there is also some evidence of the stabilizing efforts. Rising CO_2 emissions are followed by the lower nonrenewable energy consumption and the higher renewable energy consumption. All this lowers the level of the CO_2 emissions in Romania.

Nonetheless; there is a dire need of some regulatory body that could monitor the level of CO_2 emissions added by each firm in the environment, because the profit oriented businessmen are always, on average, less concerned with the optimal level of social welfare. In addition, government must encourage the use of renewable energy consumption. This end can be achieved well if the people are made aware about detrimental consequences of rising CO_2 emissions. There must also be the provision of subsidized products, operating with renewable energy, which could discourage the use of nonrenewable energy consumption. All these efforts will minimize the damaging consequences of the mounting CO_2 emissions in Romania.

Reference

1. Abulfotuh, F. (2007) "Energy efficiency and renewable technologies: The way to sustainable energy future" *Desalination* **209**, 275–282.
2. Amundsen, E and L. Bergman (2002), "Will Cross-Ownership Re-Establish Market Power in the Nordic Power Market?" The Energy Journal 23(2), 73-95.
3. Apergis, N and J. E. Payne (2010) "Renewable Energy Consumption and Economic Growth: Evidence from a Panel of OECD Countries" *Energy Policy* **38**, 656–660.
4. Awerbuch, S and R. Sauter (2006) "Exploiting the Oil-GDP Effect to Support Renewable Deployment" *Energy Policy* **34**, 2805–2819.
5. Chien, T and J.L. Hu (2007) "Renewable Energy and Macroeconomic Efficiency of OECD and non-OECD Economies" *Energy Policy* **35**, 3606–3615.
6. Chien, T and J.L. Hu (2008) "Renewable Energy: An Efficient Mechanism to Improve GDP" *Energy Policy* **36**, 3045– 3052.

7. Dickey, D.A. and W.A. Fuller (1979), “Distribution of the estimators for autoregressive time series with a unit root”, Journal of the American Statistical Association, 74, 427-431.
8. Domac, J., K. Richards and S. Risovic (2005) “Socio-economic Drivers in Implementing Bioenergy Projects” *Biomass and Bioenergy* **28**, 97–106.
9. Enders, Walter (2004), “Applied Econometric Time Series”, Second Edition.
10. Ewing, BT, R. Sari and U. Soytas (2007) “Disaggregate Energy Consumption and Industrial Output in the United States” *Energy Policy* **35,** 1274–1281.
11. Halicioglu, F. (2009) “An Econometric Study of CO2 Emissions, Energy Consumption, Income and Foreign Trade in Turkey” *Energy Policy* **37,** 1156–1164.
12. Krewitt, W., S. Simon, W. Graus, S. Teske, A. Zervos and O. Shaefer (2007) “The 2 Degrees C Scenario-A Sustainable World Energy Perspective” *Energy Policy* **35**, 4969–4980.
13. Lotfalipour, M. R., M. A. Falahi, and M. Ashena (2010) “Economic Growth, CO2 Emissions, and Fossil Fuels Consumption in Iran” *Energy* **35**, 5115-5120.
14. Masui, T., T. Hanaoka, S. Hikita and M. Kainuma (2006) “Assessment of CO2 Reductions and Economic Impacts Considering Energy-Saving Investments” *Energy Journal* **1**, 175–190.
15. Menegaki, Angeliki N. (2011) “Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis” *Energy Economics* **33**, 257–263.
16. Narayan, P.K., 2005. The saving and investment nexus for China: evidence from cointegration tests. Applied Economics 17, 1979-1990.
17. Sadorsky, P. (2009a) “Renewable energy consumption, CO2 emissions and oil prices in the G7 countries” *Energy Economics* **31**, 456–462.
18. Sadorsky, P. (2009b) “Renewable energy consumption and income in emerging economies” *Energy Policy* **37,** 4021–4028.
19. Sari, R and U. Soytas (2004) “Disaggregate Energy Consumption, Employment and Income in Turkey” *Energy Economics* **26**, 335– 344.
20. Sari, R, B.T. Ewing and U. Soytas (2008) “The Relationship between Disaggregate Energy Consumption and Industrial Production in the United States: An ARDL Approach” *Energy Economics* **30**, 2302– 2313.

21. Sathaye, J., P.R. Shukla and N.H. Ravindranath (2006) "Climate Change, Sustainable Development and India: Global and National Concerns" *Current Science India* **90**, 314–325.
22. Shahbaz, M., Lean, HH and Shabbir, MS., (2010). *Environmental Kuznets curve and the role of energy consumption in Pakistan*. Discussion Paper DEVDP 10/05, Development Research Unit, Monash University, Australia, 2010.
23. Shahbaz, M., Tang, C. F and Shabbir, M. S. (2011). Electricity consumption and economic growth nexus in Portugal using cointegration and causality approaches. Energy Policy, 39: 3529-3536.
24. Smyth. R and Narayan, PK., (2004). Dead man walking: an empirical reassessment of the deterrent effect of capital punishment using the bounds testing approach to cointegration. Econometric Society 2004 Australasian Meetings 332, Econometric Society.
25. Stern, N., S. Peters, V. Bakhshi, A. Bowen, C. Cameron, S. Catovsky, D. Crane, S. Cruickshank, S. Dietz, N. Edmonson, S.-L. Garbett, L. Hamid, G. Hoffman, D. Ingram, B. Jones, N. Patmore, H. Radcliffe, R. Sathiyarajah, M. Stock, C. Taylor, T. Vernon, H. Wanjie, and D. Zenghelis (2006) *Stern Review: The Economics of Climate Change*, HM Treasury: London.
26. Tiwari, Aviral K. (2011a) "Comparative performance of renewable and nonrenewable energy source on economic growth and CO2 emissions of Europe and Eurasian countries: A PVAR approach', *Economics Bulletin*, Vol. 31 no.3 pp. 2356-2372.
27. Tiwari, Aviral K. (2011b) "Energy consumption, CO2 emissions and economic growth: Evidence from India" *Journal of International Business and Economy* **12(1),** 1-38.
28. Tiwari, Aviral K. (2011c) "Energy consumption, CO2 emission and economic growth: A revisit of the evidence from India" *Applied Econometrics and International Development* (Forthcoming).
29. Tiwari, Aviral K. (2011d) "Primary energy consumption, CO2 emissions and economic growth: Evidence from India" *South East European Journal of Economics and Business* (Forthcoming).
30. Tiwari, Aviral K. (2011e) "A structural VAR analysis of renewable energy consumption, real GDP and CO2 emissions: Evidence from India" *Economics Bulletin* **31(2)**, 1793-1806.

31. Wolde-Rufael, Y. (2004) “Disaggregated industrial energy consumption and GDP: The case of Shanghai, 1952–1999” *Energy Economics* **26,** 69–75.

32. Yang, H.Y. (2000) “A note on the causal relationship between energy and GDP in Taiwan” *Energy Economics* **22**, 309-317.

33. Yang, H.Y. (2000) “A note on the causal relationship between energy and GDP in Taiwan” *Energy Economics* **22**, 309-317.

Appendix

Table-3 Variance Decomposition of NREC

Period	S.E.	Shock1	Shock2	Shock3	Shock4
1	0.1000	100	0.0000	0.0000	0.0000
2	0.1689	35.0959	2.6143	61.8883	0.4013
3	0.2554	22.8939	1.1572	75.2837	0.6650
4	0.2650	22.8195	1.3061	75.2402	0.6340
5	0.2730	24.5692	1.6006	71.6700	2.1600
6	0.2739	24.6625	1.7663	71.2166	2.3545
7	0.2769	25.5514	1.8695	69.8119	2.7670
8	0.2784	25.2685	1.8875	70.0935	2.7502
9	0.2811	25.3964	1.8885	69.9076	2.8073
10	0.2812	25.3792	1.8874	69.8539	2.8793

Shock1-4 represents NREC, REC, GDP and CO2 respectively.

Table-4 Variance Decomposition of REC

Period	S.E.	Shock1	Shock2	Shock3	Shock4
1	0.1004	0.990099	99.0099	0.0000	0.0000
2	0.1177	7.5331	79.4147	12.5240	0.5281
3	0.1490	7.2341	54.1842	11.1198	27.4618
4	0.1839	21.0530	38.8702	7.5383	32.5383
5	0.2024	19.5201	32.1185	21.4814	26.8798
6	0.2145	22.9913	29.3011	21.0330	26.6744
7	0.2220	24.2024	27.4296	21.3889	26.9789
8	0.2231	24.6153	27.3559	21.1719	26.8568
9	0.2257	25.2126	26.7757	21.2158	26.7958
10	0.2259	25.2067	26.7821	21.2585	26.7525

Shock1-4 represents NREC, REC, GDP and CO2 respectively.

Table-6 Variance Decomposition of CO2

Period	S.E.	Shock1	Shock2	Shock3	Shock4
1	0.10182	1.4122	1.1671	0.9645	96.4561
2	0.1562	6.4689	1.7618	48.0622	43.7070
3	0.2436	7.0268	0.7398	74.2275	18.0056
4	0.2685	7.5500	0.6118	76.9324	14.9056
5	0.2744	7.9993	0.7809	74.9065	16.3131
6	0.2751	8.0171	0.8605	74.7872	16.3350
7	0.2755	8.2217	0.8676	74.6032	16.3073
8	0.276	8.1723	0.8774	74.7199	16.2302
9	0.2778	8.2045	0.8694	74.8605	16.0653
10	0.2782	8.1852	0.8669	74.9173	16.0304

Shock1-4 represents NREC, REC, GDP and CO2 respectively.