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Comparative performance of renewable and nonrenewable energy source on economic growth and CO2 emissions of Europe and Eurasian countries: A PVAR approach

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Abstract

In the study, we analyzed the relative performance of RES and NRES on economic growth in European and Eurasian countries in a panel framework. The dynamics of these variables are also analyzed in relation to CO2 emissions. We used PVAR approach for analysis for the period 1965 to 2009 and find that growth rate of NRES has negative impact on the growth rate of GDP and also increase CO2 emissions. The imapct of RES, in general, is found to be positive on the growth rate of GDP. Hence, we recommend the reduction of the consumption of NRES in order to attain higher economic growth, increase economic efficiency and employment with clean and sustainable environment in Europe and Eurasian countries.

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1. Introduction

The increasing threat of global warming and climate change has attracted attention about the relationship between economic growth, energy consumption, and environmental pollution. Though Global warming depends on worldwide Greenhouse Gas (GHG) emissions, its consequences differ among countries, based on the latter's' social and natural characteristics. Stern et al. (2006) pointed out that if no action is taken to reduce GHG emissions, the concentration of GHGs in the atmosphere could double as early as 2035 from its pre-industrial level. This implies that in the short run, global average temperature may rise by over 2°C. In the longer term, there is a greater than a 50% chance that this rise in temperature would exceed 5°C. Stern et al. (2006) emphasize that this radical change in temperatures would affect all countries. Among them, the earliest and the hardest hit would be on the poorest and populous nations, even though they contributed least to GHG emissions.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change was a cornerstone in the promotion of Renewable Energy Sources (RES). However, by itself it became unsuccessful in addressing the issues pertaining to the climate change challenge and came up with a judgmental and adequate roadmap (Sathaye et al., 2006). Renewable energy sources are accepted as one of the key solutions to climate change and the increasing energy demand. Every country, either developing or developed is promoting and adopting policies to switch over the energy consumption towards renewable energy sources. In this line since 1997, the European Union (EU) has been working towards supply of RES and to boost the production of RES, and the EU issued the 2001/77/EC Directive on electricity production from RES in the year of 2001 (European Commission, 2001). Further, the commission set a target of achieving 22% electricity production from RES in the year 2010, compared to 14.5% in 1999 (Míguez et al., 2006). Additionally, in the year of 2009, the European Commission issued the 2009/28/EC Directive on promotion of the use of energy from renewable sources and set mandatory national targets for individual country for the share of RES in gross final energy consumption that is to be achieved by 2020. Further, the Directives of European Commission stipulates that for each member state at least 10% of its final energy consumption in the transport sector must come from the renewable energy sources.

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. However, few attempts have been made to explain the plausible mechanism for such case. Domac et al. (2005) and Chien and Hu (2007) suggest that renewable energy might increase the macroeconomic efficiency and hence bring higher economic growth. This either might be due to the expansion of business and new employment opportunities brought by renewable energy industries that resulted in economic growth 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.

Masui et al. (2006) suggested some effective ways to address the issues related to the climate change; 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.

With this background, in the present study we set three objectives. Firstly, to compare the relative performance of RES and Nonrenewable Energy Source (NRES) on the economic growth in European and Eurasian countries. Secondly, to analyze, whether there is any sensitivity in the dynamic relationship of these variables with the inclusion of CO_2 emissions. Thirdly, to analyze the dynamics of RES, NRES and economic growth to CO_2 emissions. For the purpose of analysis, we adopted Panel Vector Autoregressive (PVAR) approach. To the best of our knowledge, it is the first time that such an approach is taken for this kind of an analysis.

2. A brief review of literature

Though, 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. This group also includes those studies which find positive impact of energy consumption (at 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 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. In a very recent study on India, Tiwari (2011d) used SVAR approach and show that a positive shock on the consumption of RES increases GDP and decreases CO_2 emissions and a positive shock on GDP have 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.

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

Second are the studies that find a unidirectional causality running from economic growth or gross domestic product 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, Falahi and Ashena (2010) found that carbon emissions, petroleum products, and total fossil fuels consumption do not lead to economic growth.

3. Empirical methodology

For analaying, the dynamics of the relationship between RES and NRES with CO_2 emissions and GDP growth we use a panel-data vector autoregression methodology. To the best of our knowledge, this kind of investigation has not been done till date and we are the first to use PVAR approach for this type of study. The advantage of this technique is that it combines the traditional VAR approach, which treats all the variables in the system as endogenous, with the panel-data approach, which allows for unobserved individual heterogeneity. Most of the country case studies have analysed the dynamics among the test variables in VAR and/or VECM framework and group specific studies have used the panel data techniques by employing fixed and/or random effect and/or GMM approach and/or panel cointegration and Granger-causality analysis. Therefore, our study has advantages over others by overcoming the limitations of both sets of studies. We specify a second order VAR model as follows:

$$Z_{it} = \Gamma_0 + \Gamma_1 Z_{it-1} + \Gamma_2 Z_{it-2} + \mu_i + d_{c,t} + \varepsilon_t \quad (1)$$

where z_t is either a two variable vector (LnGDP and LnHec or LnGDP and LnCoal) or three-variable vector (LnGDP, LnHec and $LnCO_2$ or LnGDP, LnCoal and $LnCO_2$).[2] We use *i* to index countries and *t* to index time, τ are the parameters and ε is white noise the error term. Further to calculate the impulse-response functions which describe the reaction of one variable to the innovations in another variable in the system while holding all other shocks equal to zero, we need to decompose the residuals in a such a way that they become orthogonal as the actual variance-covariance matrix of the errors is unlikely to be diagonal. The usual convention is to adopt a particular ordering and allocate any correlation between the residuals of any two elements to the variable that comes first in the ordering.[3] The identifying assumption is that the variables that come earlier in the ordering affect the following variables contemporaneously, as well as with a lag. The variables that come later affect the previous variables only with a lag. In other words, the variables that appear earlier in the systems are more exogenous and the one that appear later are more endogenous.[4] In our specification, we assume that current shocks to the GDP have an effect on the contemporaneous value of LnHec, LnCoal and $LnCO_2$ emissions while LnHec, LnCoal and $LnCO_2$ emissions has an effect on the GDP with a lag.

In applying the VAR procedure to panel data, we need to impose the restriction so that the underlying structure is same for each cross-sectional unit. Since this constraint is likely to be violated in practice, one way to overcome the restriction on parameters is to allow for "individual heterogeneity" in the levels of the variables by introducing fixed effects, denoted by μ_i in the model (Love and Zicchino, 2006). Since the fixed effects are correlated with the regressors due

[2] It is important to mention that in the study we measured renewable energy sources (RES) by the Hydroelectricity consumption (denoted by Hec) and nonrenewable energy sources (NRES) by the Coal consumption (denoted by Coal). Countries incorporated for the analysis in the study are: Austria, Belgium & Luxembourg, Bulgaria, Finland, France, Germany, Greece, Republic of Ireland, Italy, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, and United Kingdom. Ln denoted natural logarithms of the variables considered. Annual data of GDP is accessed from the Conference board and Hec and CO_2 emissions are accessed from the http://www.bp.com/bodycopyarticle.do?categoryId=1&contentId=7052055. Study period is 1965-2009. Our panel includes 16 countries in total and rests are avoided because of unavailability of the data for the period we considered for analysis in our study.

[3] This procedure is known as Choleski decomposition of variance-covariance matrix of residuals and is equivalent to transforming the system in a "recursive" VAR for identification purposes. See Hamilton (1994) for the derivations and discussion of impulse-response functions.

[4] More formally, if a variable *x* appears earlier in the system than a variable *y*, then *x* is weakly exogenous with respect to *y* in the short run.

to lags of the dependent variables, the mean-differencing procedure commonly used to eliminate fixed effects would create biased coefficients. To avoid this problem we use forward mean-differencing, also referred to as the 'Helmert procedure' (see Arellano and Bover, 1995). This procedure removes only the forward mean, i.e., the mean of all the future observations available for each country-year. This transformation preserves the orthogonality between transformed variables and lagged regressors, so we can use lagged regressors as instruments and estimate the coefficients by system GMM.[5] Further, our model also allows for country-specific time dummies, $d_{c,t}$ which are added to model (1) to capture aggregate, country-specific macro shocks that may affect all countries in the same way. We eliminate these dummies by subtracting the means of each variable calculated for each country-year. Further, to analyze the impulse-response functions we need an estimate of their confidence intervals. Since the matrix of impulse-response functions is constructed from the estimated VAR coefficients, their standard errors need to be taken into account. We calculate standard errors of the impulse response functions and generate confidence intervals with 1000 Monte Carlo simulations.[6] Finally, we also present variance decompositions, which show the percentage of the variation in (one) variable(s) that is explained by the shock to another variable, accumulated over time. The variance decompositions show the magnitude of the total effect. We report the total effect accumulated over the 10 years.

4. Results and discussion

Before going ahead with PVAR approach, we analysed the stationarity property of the data by using a battery panel unit root tests. Panel unit root tests that we used are the LLC test (Levin, Lin and Chu, 2002), IPS test (Im, et al., 2003) and ADF and PP type Fisher Chi-square tests of MW (Maddala and Wu, 1999). Results of panel unit root tests of variables analysed are presented in Appendix 1. We find form the analysis of panel unit root tests that LnHec and $LnCO_2$ emissions are stationary whereas LnGDP and LnCoal are nonstationary in the level form. This implies that order of integration of the variables in the question is not same and therefore we cannot proceed for cointegration analysis. It is important to note that there is one bivariate case when order of integration of the variables is same and that is LnGDP and LnCoal. Therefore, for this case we use two tests of cointegration namely, Pedroni (2004) and Kao (1999), to test the presence of cointegration relationship. And we do not find any evidence of cointegration between LnGDP and LnCoal.[7] Therefore, in order analyse the dynamics between the test variables we first transformed the nonstationary variables (namely LnGDP and LnCoal)

[5] In our case the model is "just identified," i.e. the number of regressors equals the number of instruments, therefore system GMM is numerically equivalent to equation-by-equation 2SLS.

[6] In practice, we randomly generate a draw of coefficients of model (1) using the estimated coefficients and their variance covariance matrix and re-calculate the impulse-responses. We repeat this procedure 1000 times (we experimented with a larger number of repetitions and obtained similar results). We generate 5th and 95th percentiles of this distribution that we use as a confidence interval for the impulse-responses.

[7] Results of cointegration are not given for brevity of presentation however; results are available upon request to the authors. It is important to note that we analyzed the cointegration relationship by disregarding the nature of the integration of the variables and found no evidence of cointegration. These results also will be available upon request to the author.

into first difference form so that all analysed variables are stationary. This is important to obtain efficient results in PVAR framework. Next, we estimate the coefficients of the system given in (1) after the fixed effects and the country time dummy variables have been removed. In Table 1, we report the results of two variables vector (D(LnGDP) and LnHec in model 1 and D(LnGDP) and D(LnCoal) in model 2). Further, we report results of three-variable vector (D(LnGDP), LnHec and $LnCO_2$ in model 1 and D(LnGDP), D(LnCoal) and $LnCO_2$ in model 2) in Table 2. Finally, we present graphs of the impulse-response functions. Fig. 1 and 2 reports the graphs of impulse responses for the models with two variables and Fig. 3 and 4 reports impulse-response functions of three variables and the 5% error bands generated by Monte Carlo simulation with 1000 replications.

Table 1: Results of a two-variable PVAR model

Response of	Response to			
	$D(LnGDP_{(t-1)})$	$LnHec_{(t-1)}$	$D(LnGDP_{(t-2)})$	$LnHec_{(t-2)}$
Model 1: GDP and Hec				
$D(LnGDP_{(t)})$	.95243987*** (3.0142616)	.04833688 (.94121321)	.42919119 (1.6512255)	.05171544 (1.5920683)
$LnHec_{(t)}$	-.22301458 (-.1586927)	.5539288** (2.5586338)	-.63038903 (-.59573174)	.22754381 (1.557396)
Model 2: GDP and Coal				
	$D(LnGDP_{(t-1)})$	$D(LnCoal_{(t-1)})$	$D(LnGDP_{(t-2)})$	$D(LnCoal_{(t-2)})$
$D(LnGDP_{(t)})$	.54705804*** (9.5857872)	.00262513 (.40475333)	.13466062** (2.1892089)	-.01129953* (-1.8028889)
$D(LnCoal_{(t)})$	.4681971* (1.7828432)	.06757775 (1.1344484)	-.26404234 (-1.0325252)	-.01431624 (-.30856176)
Two variable PVAR model is estimated by GMM, country-time and fixed effects are removed prior to estimation. Reported numbers show the coefficients of regressing the row variables on lags of the column variables. Heteroskedasticity adjusted *t*-statistics are in parentheses. ***, ** and * indicates significance at 1%, 5% and 10% level, respectively.				
Source: Authors' calculation				

It is evident from the model 1 in Table 1 that response of GDP, and Hec to one year lagged values of GDP and Hec respectively is positively significant. Further, evidence show that effect of one and two year lagged value of Hec on the growth rate of GDP is positive but not significant whereas effect of one and two year lagged growth rate of GDP on Hec is negative and not significant.

Now if we see the results of model 2 in Table 1 we find that response of growth rate of GDP to one and two year's lagged value of growth rate of GDP is positive and significant. This implies that India's historical GDP growth rate has positive impact on the current growth rate of the GDP, whereas two year lagged growth rate of coal consumption has negative impact on the current year's growth rate of GDP. Interestingly, impact of growth rate of Coal consumption on the growth rate of GDP is negative and significant. Response of growth rate of Coal to the one year lagged value of the growth rate of GDP is positive and significant.

Hence, from Table 1 we have one very interesting finding that growth rate in the consumption of Coal has negative and significant effect on the growth rate of GDP and viceversa, whereas consumption of Hec has positive and significant impact on the growth rate of GDP. Next, we present results of the three variables model in Table 2 in order to see the sensitivity of dynamic relationship between GDP and RES and NRES consumption analysed above.

Table 2: Results of a three-variable PVAR model

Response of	Response to					
	D(LnGDP $_{(t-1)}$)	LnHec$_{(t-1)}$	LnCO$_{2(t-1)}$	D(LnGDP $_{(t-2)}$)	LnHec$_{(t-2)}$	LnCO$_{2(t-2)}$
Model 1: GDP, Hec and CO_2						
D(LnGDP $_{(t)}$)	.78923221** (2.4191647)	-.08321354** (-2.1423569)	.26759815 (1.217005)	.33375073 (1.1321554)	-.05549013 (-1.3180584)	-.08456204 (-.8806205)
LnHec $_{(t)}$	-.17745416 (-.16165688)	.69376188*** (4.6835189)	-.13827903 (-.1808813)	-.55032357 (-.5892443)	.32446004** (2.3163577)	-.04089073 (-.11923696)
LnCO2$_{(t)}$	.67373996 (1.5650063)	-.02971762 (-.5792394)	1.2875821*** (4.3685332)	.27450052 (.73312641)	-.06291001 (-1.097344)	-.16768661 (-1.3232477)
Model 2: GDP, Coal and CO_2						
	D(LnGDP $_{(t)}$)	D(LnCoal $_{(t-1)}$)	LnCO$_{2(t-1)}$	D(LnGDP $_{(t-2)}$)	D(LnCoal $_{(t-2)}$)	LnCO$_{2(t-2)}$
D(LnGDP $_{(t)}$)	-.24376569 (-.58232501)	.00658338 (.3220064)	-.31151037 (-1.4304693)	-.50711045 (-1.38973)	-.01690924 (-.89558227)	.12175518 (1.0098285)
D(LnCoal $_{(t-1)}$)	-3.0954064 (-1.4340718)	.14601328 (1.3130955)	-1.8634235 (-1.6874152)	-3.2853992* (-1.77833)	-.05444817 (-.53765814)	.9418335 (1.5345119)
LnCO$_{2(t)}$	-.05836558 (-.14855914)	-.03288645* (-1.8747902)	.88766234*** (4.6287605)	-.3735963 (-1.151759)	-.00769605 (-.48164556)	-.0362994 (-.34877472)
Three variable PVAR model is estimated by GMM, country-time and fixed effects are removed prior to estimation. Reported numbers show the coefficients of regressing the row variables on lags of the column variables. Heteroskedasticity adjusted *t*-statistics are in parentheses. *** , ** and * indicates significance at 1%, 5% and 10% level, respectively.						
Source: Authors' calculation						

It is evident from model 1 in Table 2 that response of the growth rate of GDP to lagged value of growth rate of GDP is not sensitive to the inclusion of CO_2 emissions. However, the response of growth rate of GDP to lagged value of Hec is sensitive to the inclusion of CO_2 emissions in a way that not only one year lagged values of Hec become negative but also coefficient is statistically significant at 5% level of significance. Response of Hec to lagged values of Hec and growth rate of GDP is not sensitive to the inclusion of CO_2 emissions. Further, evidence shows that, as expected, though insignificant, growth rate of GDP and Hec respectively, have positive and negative impact on CO_2 emissions.

Now if we see the results of model 2 in Table 2 we find that response of growth rate of GDP to lagged value of growth rate of GDP and Hec is much sensitive to the inclusion of CO_2 emissions. Similarly, we find results for growth rate of Coal consumption. Results of model 2 of Table 2 show that two year lagged growth rate of GDP has significantly negative impact on the growth rate of Coal consumption contrary to the results of model 2 of Table 1 in which though effect was negative and it was insignificant. One point that is more important is that, contrary to our expectation, growth rate of Coal consumption is found to be having negative impact on the CO_2 emissions.

Thus, from the above discussion we find that results of two variable models are sensitive to the inclusion of the third variable. Therefore, on the relative performance of RES and NRES we are unable to draw any convincing conclusion. Hence, to achieve our objective we moved ahead to analyze the variance decomposition. We present the results of variance decompositions of bivariate models in Table 3.

Table 3: Variance decomposition of a two-variable PVAR model

	D(LnGDP)	LnHec
Model 1: D(LnGDP) and Hec		
D(LnGDP)	.62668551	.37331449
LnHec	.70125085	.29874915
Model 2: D(LnGDP) and Coal		
	D(LnGDP)	D(LnCoal)
D(LnGDP)	.99628512	.00371488
D(LnCoal)	.03851825	.96148175
Percent of variation in the row variable (10 periods ahead) explained by column variable.		
Source: Authors' calculation		

It is evident from Table 3 that growth rate of GDP and Hec respectively explains, in model 1, about 63% and 37% of total variation, 10 periods ahead, in growth rate of GDP. Further, growth rate of GDP and Hec respectively explains, in model 1, about 70% and 30% of total variation, 10 periods ahead, in Hec. This implies that growth rate of GDP explains most of variation in both growth rate of GDP and Hec consumption. Result of model 2 of Table 3 shows that growth rate of GDP and growth rate of Coal consumption respectively explains, about 99% and 1% of total variation, 10 periods ahead, in growth rate of GDP. While, growth rate of GDP and growth rate of Coal consumption respectively explains, in model 2, about 3.9% and 96% of total variation, 10 periods ahead, in growth rate of Coal consumption. Hence, we find that bivariate models show that explanatory power of Hec is relatively higher vis-à-vis explanatory power of growth rate of Coal consumption in growth rate of GDP.[8]

Further, to check the sensitivity of the results of VDs analysis of bivariate model we analyzed trivariate model and present results in Table 4.

[8] It is important to mention that we cannot draw the conclusion simply based on the explanatory power of the variables as one variable is measured in terms of growth rate and another is measured in level form only.

Table 4: Variance decomposition a three-variable PVAR model

	D(LnGDP)	LnHec	$LnCO_2$
Model 1: GDP, Hec and CO_2			
D(LnGDP)	.76296025	.1782843	.05875545
LnHec	.74694388	.19758065	.05547547
$LnCO_2$	.76799253	.1708405	.06116697
Model 2: GDP, Coal and CO_2			
	D(LnGDP)	D(LnCoal)	$LnCO_2$
D(LnGDP)	.94959473	.00629279	.04411248
D(LnCoal)	.83593256	.12505035	.03901708
$LnCO_2$	.16362786	.06170681	.77466534
Percent of variation in the row variable (10 periods ahead) explained by column variable.			
Source: Authors' calculation			

It is evident from model 1 in Table 4 that growth rate of GDP, Hec and CO_2 emissions respectively explains about 76%, 18% and 5.9% of total variation 10 periods ahead in growth rate of GDP. Evidence show that GDP, Hec and CO_2 emissions respectively explains about 75%, 20% and 5% of total variation, 10 periods ahead, in growth rate of Hec. Further, we find that GDP, Hec and CO_2 emissions respectively explains about 77%, 17% and 6% of total variation, 10 periods ahead, in growth rate of CO_2 emissions. This implies that explanatory power of growth rate of GDP is relatively higher in the growth rate of GDP, Hec and CO_2 emissions and explanatory power of Hec of the total variation of growth rate of GDP is about 20%.

Now if we see the results of model 2 in Table 4 we find that growth rate of GDP, growth rate of Coal consumption and CO_2 emissions respectively explains about 95%, 0.6% and 4% of total variation, 10 period ahead, in growth rate of GDP. Whereas their explanatory power for growth rate of Coal consumption is about 84%, 13% and 4%. Further, we find that growth rate of GDP, growth rate of Coal consumption and CO_2 emissions respectively explains about 16%, 6% and 77.5% of total variation in CO_2 emissions.

Hence, from table 4 we have followings observations. First, we have similar findings as obtained from the bivariate case in terms of explanatory power of the variable.[9] Growth rate of GDP explains relatively higher variation in total variation of growth rate of GDP, Hec and growth rate of Coal consumption. Explanatory power of growth rate of GDP for CO_2 emissions is sensitive and hence we have inconclusive results. Explanatory power of Hec is relatively higher in total variation of growth rate of GDP in comparison with the explanatory power of growth rate of Coal consumption.

In the final step, we present the IRFs of our bivariate models analyzed above. Figure, 1 show that response of growth rate of GDP in one standard deviation (SD) shock in growth rate of

[9] Of course, in percentage terms explanatory power of the variable has changed but relative explanatory power is unchanged.

GDP and Hec is marginally positive. Further, response of Hec in one SD shock in growth rate of GDP and Hec is negative but negligible.

Figure 1: LnGDP and LnHec

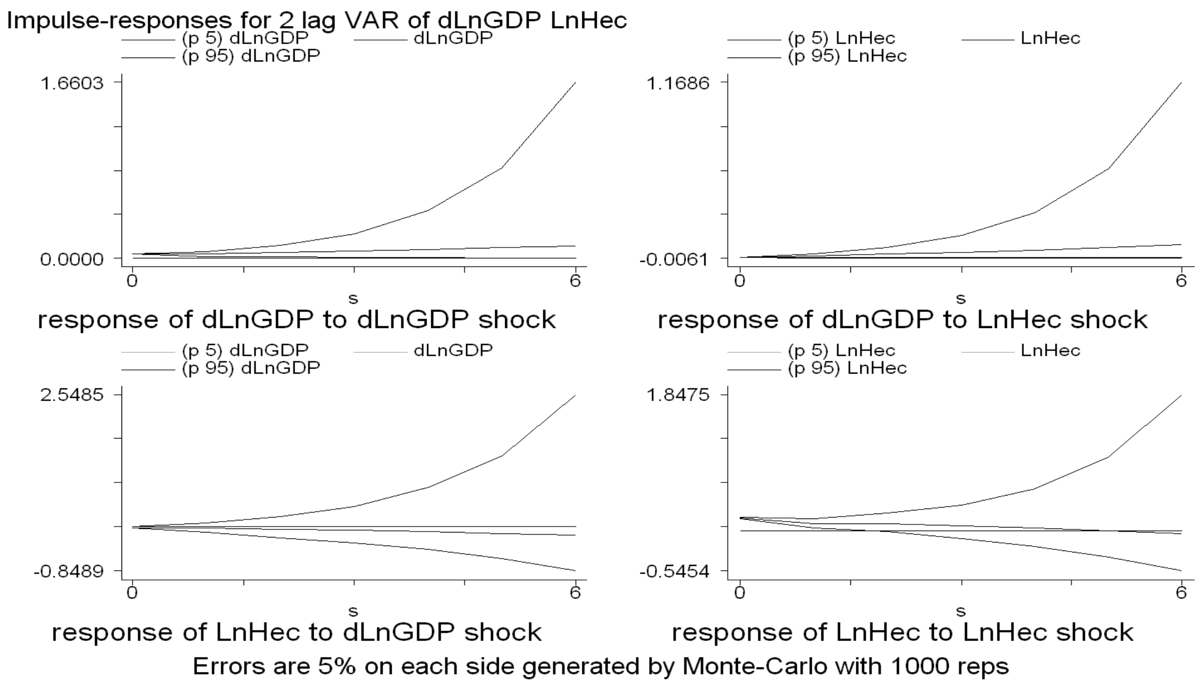


Figure 2, shows that response of growth rate of GDP in one SD shock in growth rate of GDP has a clear declining trend. Response of growth rate of GDP in one SD shock in growth rate of Coal consumption is negative which is realized after one and half year. Response of growth rate of Coal consumption in one SD shock in growth rate of Coal consumption and growth rate of GDP has a declining trend.

Figure 2: LnGDP and LnCoal

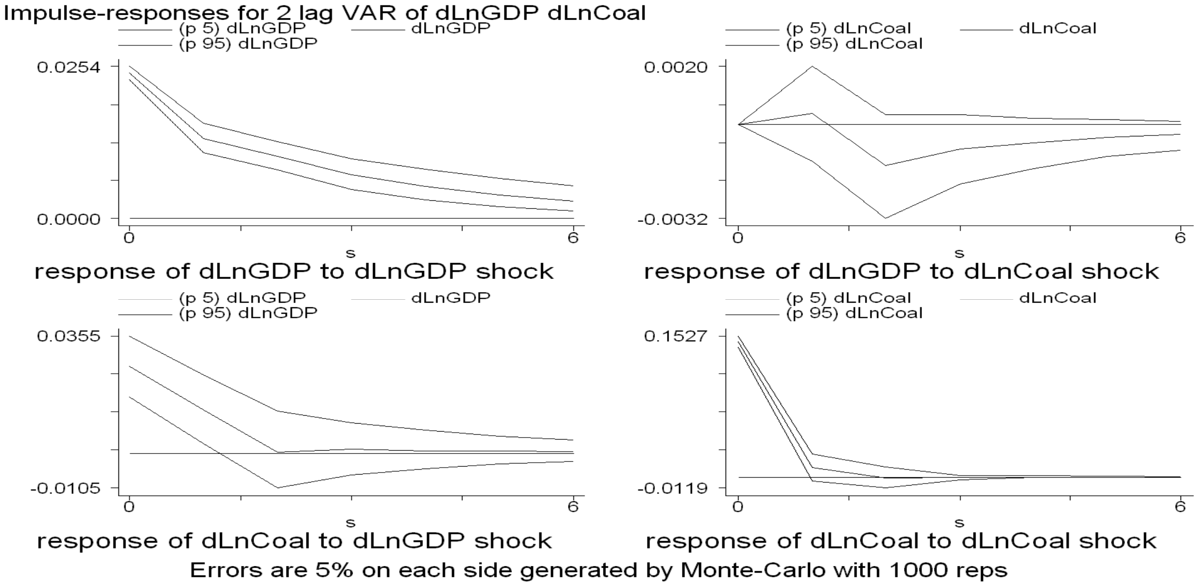
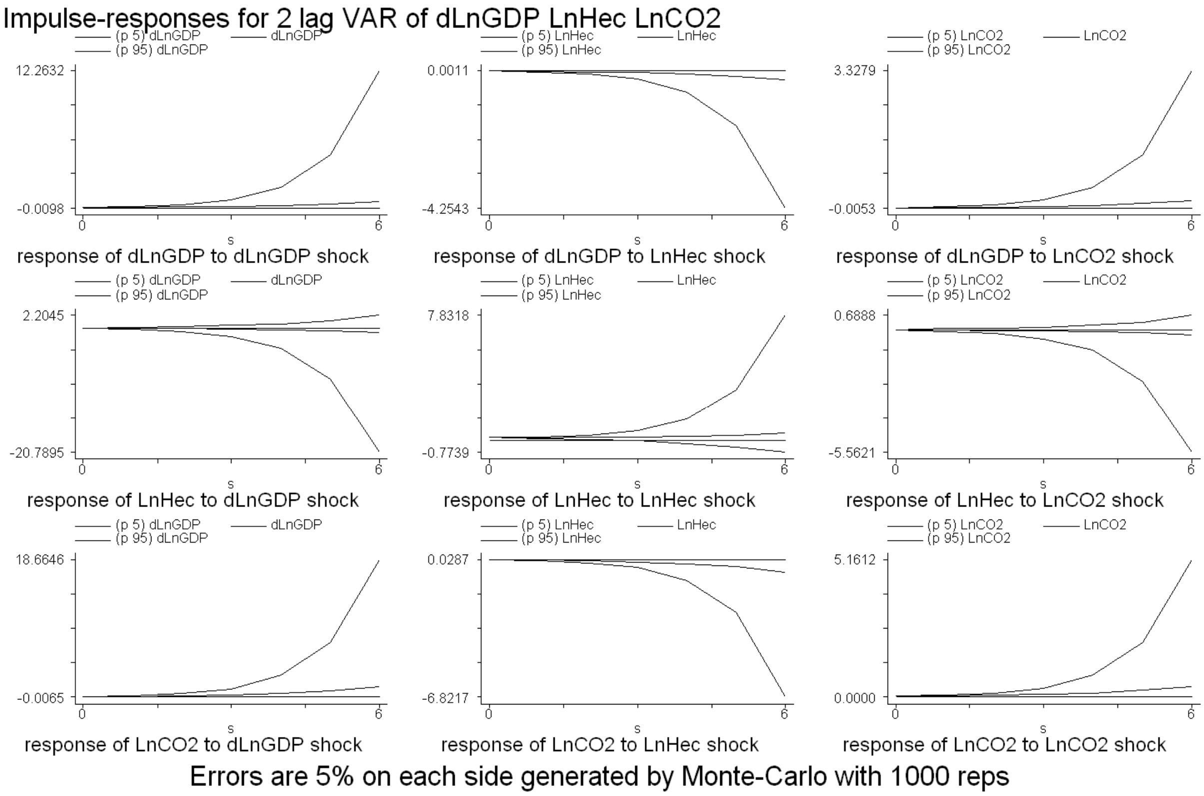


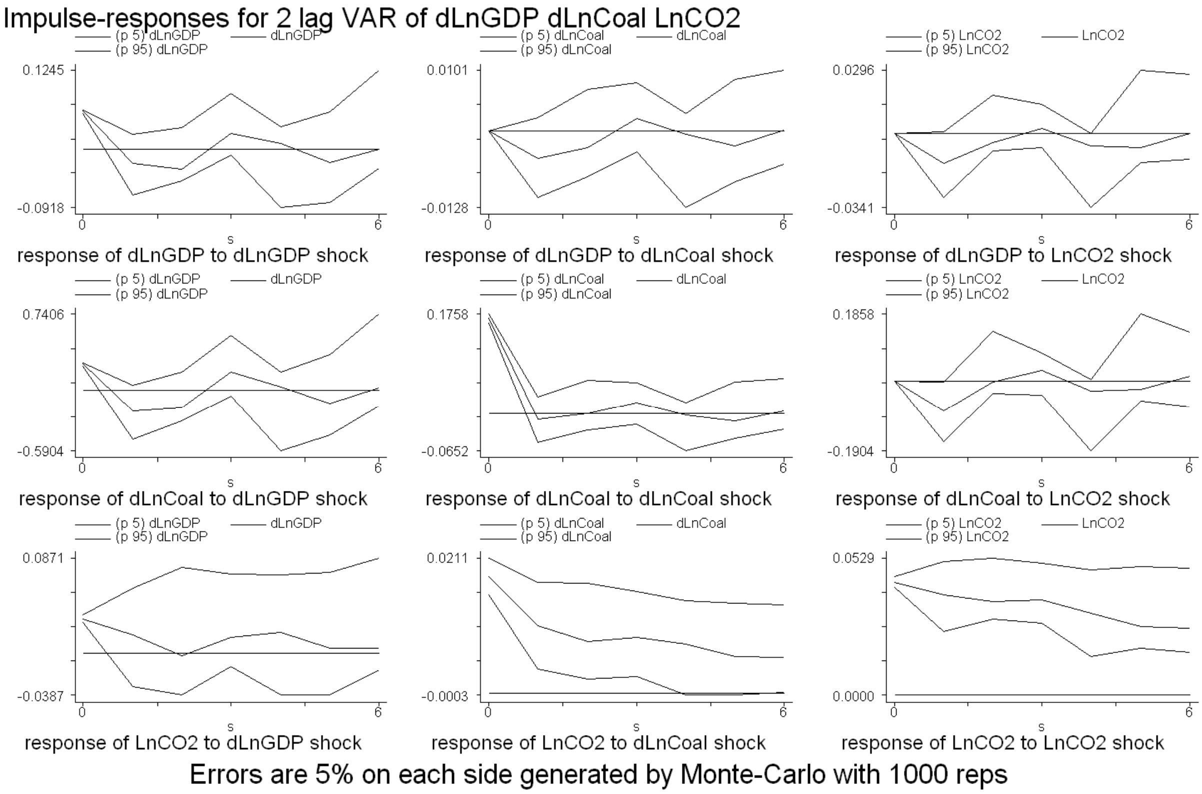
Figure 3, shows that response of growth rate of GDP in one SD shock in growth rate of GDP and CO_2 emissions marginally positive and in one SD shock in Hec is negative but negligible. Response of Hec in one SD shock in all three variables is negligible. Similarly, response of CO_2 emissions in one SD shock in all three variables is also negligible.

Figure 3: GDP, Hec and CO_2 emissions



Figure, 4 show that response of growth rate of GDP in one SD shock in growth rate of Coal consumption and CO_2 emissions is mostly negative. Similarly, response of growth rate of Coal consumption in one SD shock in growth rate of GDP is mostly negative. Importantly, response of CO_2 emissions in one SD shock in growth rate of GDP and growth rate of Coal consumption is mostly positive, as expected.

Figure 4: GDP Coal and CO_2 emissions



5. Conclusions

Recently, concerns over environmental issues have got the momentum and that has been the motivation of researchers and policy analysts. Countries have started shifting towards the consumption of RES and huge amount of foreign aid is also provided to the developing countries in the name of green aid. These issues have been addressed and analyzed by a quite a good number of researchers, however these attempts have been limited at the disaggregated level of energy resources. In this study, we contributed particularly in two ways. First, we analyzed the dynamics of the relationship between RES and NRES consumption and economic growth. Second, our analysis was based on Panel VAR (PVAR) model that has not been used in the previous studies carried out in this area. We also checked sensitivity of the dynamics of the relationship by including CO_2 emissions, which helped us to see the dynamics of the relationship between CO_2 emissions and economic growth. Period of our study is 1965-2009 and we used annual data for our study for 16 countries.

We find that growth rate of GDP has higher forecast error explanation power in case of growth rate of GDP, growth rate of Coal consumption and Hec. Further, we find that explanatory power of Hec is relatively higher in total variation of growth rate of GDP in comparison with explanatory power of growth rate of Coal consumption in the total variation in growth rate of

GDP. Results of IRFs also lead us to same conclusion. Evidence shows that response of growth rate of GDP to growth rate of Coal consumption as mostly negative. Response of growth rate of GDP in one SD shock in CO_2 emissions is mostly negative, as expected.

Therefore, this study reveals that consumption of NRES (in our case growth rate of Coal) must be reduced as it has negative impact on the growth rate of GDP and also increases CO_2 emissions and reduced energy consumption must be replaced with the increased consumption of RES as it has potential to increase growth rate of GDP and it reduces CO_2 emissions also. The other policy implication is that if it is acieved we have tremendous opportunities in terms of higher economic growth, economic efficiency and employment with clean and sustainable environment in Europe and Eurasian countries.

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Appendix 1: Results of unit root analysis of the variables analyzed

Constant and trend included in the model												
	LNCO2		LNCOAL		D(LNCOAL)		LNGDP		D(LNGDP)		LNHEC	
Method	Statistic	P-value	Statistic	P-value	Statistic	P-value	Statistic	P-value	Statistic	P-value	Statistic	P-value
Levin, Lin & Chu t*	-3.02725	0.0012	-0.21988	0.4130	-16.6351	0.0000	-0.85992	0.1949	-3.47110	0.0003	-10.3505	0.0000
Im, Pesaran and Shin W-stat	-2.45649	0.0070	-0.68631	0.2463	-18.6201	0.0000	-0.08073	0.4678	-9.08247	0.0000	-10.1221	0.0000
ADF - Fisher Chi-square	58.3383	0.0030	44.4709	0.0703	312.455	0.0000	40.8614	0.1354	141.630	0.0000	168.170	0.0000
PP - Fisher Chi-square	46.0047	0.0519	40.4574	0.1450	606.512	0.0000	23.6440	0.8570	123.917	0.0000	163.795	0.0000
Source: Authors' calculation												