Jagannath University Journal of Business Studies, Vol. 3, No. 1& 2, 183-191, 2013

A NOTE ON THE CAUSAL LINK AMONG ECONOMIC GROWTH, ENERGY CONSUMPTION AND CO_2 EMISSION IN CHINA

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Abstract

This study investigates the causal relationship among economic growth, energy consumption and CO_2 emission in China using the most recent time series data for the period of 1976-2010. Johansen cointegration technique and error correction methods are employed to examine the long run and the short run relationship among economic growth, energy consumption and CO_2 emission in China. We use innovation accounting approach to find the causal link between the variables. Results suggest that there is long run cointegrating relationship between economic growth and energy consumption in China in both the short run and the long run. The study shows no causal link between energy consumption and economic growth and also between CO_2 emission and economic growth. The finding is partially consistent with theoretical and empirical considerations.

Keywords: Energy Consumption, Economic Growth, China, Co integration.

Introduction

China is presently the fastest growing economy in the world. After the launching of economic reforms and open-door policy, China has experienced rapid economic growth. With the staggering double-digit growth, the consumption of primary energy has increased significantly. The total energy consumption has risen by 3.5 times during the period from 1992 to 2009. The coal consumption in China accounts for approximately 69.5% of the total primary energy consumption in 2007 and 70.7% in 1978 only decreased by about 1.2% which is over four times more than the average level in developed countries. The coal consumption accounts for 70% of the sort dust emissions and 90% of CO_2 emissions. In 1990's, China's CO_2 emissions represented 11% of the world's total. It reached 16% in 2007. It is one of the top five sources of greenhouse gases in the world. Therefore, China is one of the major countries responsible for the increasing threat of global warming and climate change which has been a major ongoing concern to environment and development experts. Thus the impacts of global warming and climate change on the world economy have been assessed intensively by researchers both in developing and developed countries. As a result, the forecasts of CO_2 emissions, energy use and economic growth constitute a vital part of environmental energy policy in many developing and developed countries and as such, perhaps the most important information a policy maker may need to address global warming is the causal relationship between energy consumption and economic growth.

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The major source for energy consumption is power sector and the power sector (electricity) is a major source of CO_2 emission. The impact of the oil shocks of the 1970s upon the fuel-mix of a number of high-income economies was such that it has negated the otherwise strong association between CO_2 emission and economic prosperity in high income economies. Environmental concerns about climate change along with volatile oil market, the persistent need for energy security and the global trend towards the deregulation and privatization of energy markets have recently led a number of countries to re-examine their renewable energy policies (Bradbrook and Wawryk, 2002) and China too desperately needs that. To the best of our knowledge, the literature on the causal link between energy consumption and economic growth and between CO_2 emission and economic growth in China is not enough despite the fact that it is the largest emitter of CO_2 among the developing countries.

Empirics

The relevant literature shows two strands of link between energy consumption and CO_2 emissions i.e. economic growth and CO_2 emissions and, economic growth and energy consumption. The dominating relationship between economic growth and CO_2 emissions has received great attention from researchers around the world. The relationship between CO_2 emissions and economic growth is termed as EKC[1]. The association between economic growth and CO_2 emissions reveals that economic growth is linked with high CO_2 emissions initially and CO_2 emissions tends to decrease as an economy achieves turning point or threshold level of economic growth.

The empirical studies of EKC started by Grossman and Krueger (1991) and followed by Lucas et al. (1992), Wyckoff and Roop (1994), Suri and Chapman (1998), Heil and Selden (1999), Friedl and Getzner (2003), Stern (2002), Nohman and Antrobus (2005), Dinda and Coondoo (2006) and Coondoo and Dinda (2008). Existing studies seem to present mixed empirical evidences on the validity of EKC. Song et al. (2008), Dhakal (2009), and Jalil and Mahmud (2009) supported the existence of EKC in China. The findings of Fodha and Zaghdoud (2010) revealed the existence of EKC between the SO_2 emissions and economic growth but not for the CO_2 emissions in Tunisia. In contrast, Akbostanci et al. (2009) did not support the existence of EKC in Turkey. They argued that CO_2 emissions are automatically reduced due to the rapid pace of economic growth.

On the other hand, the relationship between energy consumption and economic growth has been investigated extensively as well. For example, Kraft and Kraft (1978) for USA, Masih and Masih (1997) for Taiwan and Korea, Aqeel and Butt (2001) for Pakistan, Wolde-Rufael (2006) for African, Narayan and Singh (2007) for Fiji, Reynolds and Kolodzieji (2008) for Soviet Union, Chandran et al. (2009) for Malaysia, Narayan and Smyth (2009) for Middle Eastern and Yoo and Kwak (2010) for South American countries concluded that energy consumption causes economic growth. Opposite causality is also found running from economic growth to energy consumption by Altinay and Karagol (2004) and Halicioglu (2009) for Turkey, Squalli (2006) for OPEC, Yuan et al. (2007) for China and Odhiambo (2009) for

[1] The relationship is described by the linear and non-linear terms of GDP per capita in the model.

Tanzania. Bivariate causality between energy consumption and economic growth is also documented by Asafu-Adjaye (2000) for Thailand and the Philippines.

Recent literature documented alliance of economic growth with energy consumption and environmental pollution to investigate the validity of EKC. The relationship among economic growth, energy consumption and CO_2 emissions have also been researched extensively both in the country case and panel studies. Ang (2007) found stable long run relationship among economic growth, energy consumption and CO_2 emissions for French economy while Ang (2008) also got similar results for Malaysia. Ang (2007) showed that causality is running from economic growth to energy consumption and CO_2 emissions in the long run but energy consumption causes economic growth in short run. In the case of Malaysia, Ang (2008) reported that output increases CO_2 emissions and energy consumption. Ghosh (2010) documented that no long run causality between economic growth and CO_2 emissions and bivariate short run causality in India.

For the panel studies, Apergis and Payne (2009) investigated this relationship for six Central American economies using panel VECM. It is evident that energy consumption is positively linked with CO_2 emissions and EKC hypothesis has been confirmed. Lean and Smyth (2010) and Apergis and Payne (2010) reached the same conclusion for the case of ASEAN countries and Commonwealth of Independent States respectively. Narayan's (2010) empirical evidence also validates the EKC hypothesis for 43 low income countries. In addition, Lean and Smyth (2010) noted long run causality running from energy consumption and CO_2 emissions to economic growth but in the short run, energy consumption causes CO_2 emissions. On the other hand, Apergis and Payne (2010) found that energy consumption and economic growth causes CO_2 emissions while bivariate Granger causality exists between energy consumption and economic growth and between energy consumption and CO_2 emissions.

Data and Methodological Framework

We used annual time series data for the period of 1976-2010 obtained from the World Development Indicators Database 2011 for this study. Vector Auto Regression (VAR) approach is widely used to investigate the dynamics of the relationship between two variables. The present study employs the innovation Accounting Technique (Impulse response function and variance decomposition) to estimate the causal relationship among the variables. It also attempts to estimate the forecast error variance decomposition that allows inferences to be concluded with the proportion of movements in particular time periods due to its own shocks and shocks from other variables in the VAR. By using VAR, one can check the impact of a "shock" in a particular variable to find out the impact on other variables and future values of shocked variables are also included.

This advanced approach breaks down the variance of the forecast error for each variable following a "shock" in a particular variable that makes possible to identify which variable affects strongly and its impact. For example, a shock in energy consumption causes significant change in economic growth but a shock in the economic growth has insignificant effect on energy consumption. Impulse response function on the other hand investigates the time path of the effects of shocks of independent variables. This approach also determines how each variable responds over time to the first "shocks" in other variables. According to variance decomposition which breaks down the forecast error for energy consumption, CO_2 emission and economic growth, if CO_2 emission and energy consumption explain more of the variance in economic growth, it will be concluded that Granger cause economic growth and vice versa. In the light of the above discussion, one may establish a VAR system of the following form;

$$V_t = \sum_{i=1}^{k} \delta_i V_{t-1} + \eta_t \text{ ....(1)}$$

Where,

V_t = (LY, CO_2, EN)

$\eta_t = (\eta_{LY}, \eta CO_2, \eta_{EN})$

$\delta_i - \delta_k$ are three by three matrices of coefficients and η is a vector of error terms. LY = GDP in real terms and CO_2 = Carbon dioxide emission and EN= Energy Consumption

Table 1: Descriptive Statistics & Correlation

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	CO	En	Y
CO	14.646	14.693	15.692	13.683	0.551	0.0003	2.118	1	0.983	0.985
EN	6.609	6.585	7.302	6.143	0.294	0.5404	2.888	0.983	1	0.961
Y	26.817	26.783	28.529	25.396	0.975	0.1135	1.709	0.985	0.961	1

Results and Discussion

Table 1 shows the descriptive statistics and correlation matrix. We see that for all three variables, standard deviation is far less than the mean which tells about data homogeneity. Also the correlation coefficient is very high implying strong linear relationship among economic growth, CO_2 emission and energy consumption. We conducted PP (Phillips-Peron) and KPSS (Kwiatkowski-Phillips-Schmidt-Shin) tests to determine the order of integration of the variables, economic growth, CO_2 emission and energy consumption. Table 2 reports that all the variables are stationary at first difference with constant and trend.

Table 2: Unit root test results

Variables	ADF		PP	
	Intercept	Trend and Intercept	Intercept	Trend and Intercept
Co	0.018145	-2.91257	0.1141	-1.98348
En	0.527245	-1.99566	1.07945	-0.81169
Y	1.352752	-4.39122***	2.226971	-2.78739
Δco	-3.51331***	-3.48893**	-3.51331***	-3.48893*
Δen	-3.12006**	-3.28875*	-3.12006**	-3.28976*
Δy	-2.64858*	-3.12496	-3.79057***	-4.19472**

Table 3 shows the selection of optimal lag length through different methods which are 3. Johansen cointegration test results are produced in table 4 which indicates that there is at least two cointegrating vectors among the variables confirming long run association between CO_2 emission, energy consumption and economic growth.

Table 3: Lag Length selection criteria

Endogenous variables: Y CO EN
Exogenous variables: C
Sample: 1971 2007
Included observations: 34

Lag	LogL	LR	FPE	AIC	SC	HQ
0	47.46524	NA	1.47e-05	-2.615603	-2.480924	-2.569673
1	226.7032	316.3024	6.59e-10	-12.62960	-12.09089	-12.44589
2	245.8487	30.40747*	3.68e-10*	-13.22639	-12.28364*	-12.90489*
3	255.1048	13.06739	3.76e-10	-13.24146*	-11.89467	-12.78216

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 4: Johansen Co-integration test

Sample (adjusted): 1973 2007
Included observations: 35 after adjustments
Trend assumption: Linear deterministic trend
Series: Y CO EN
Lags interval (in first differences): 1 to 1
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.467054	31.51866	29.79707	0.0314
At most 1	0.235607	9.491918	15.49471	0.3218
At most 2	0.002522	0.088375	3.841466	0.7662

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Regression Results

$$Y = 0.372694 + 2.171701\ CO - 0.81146\ EN$$

(0.41291) (8.00656) (-1.59629)

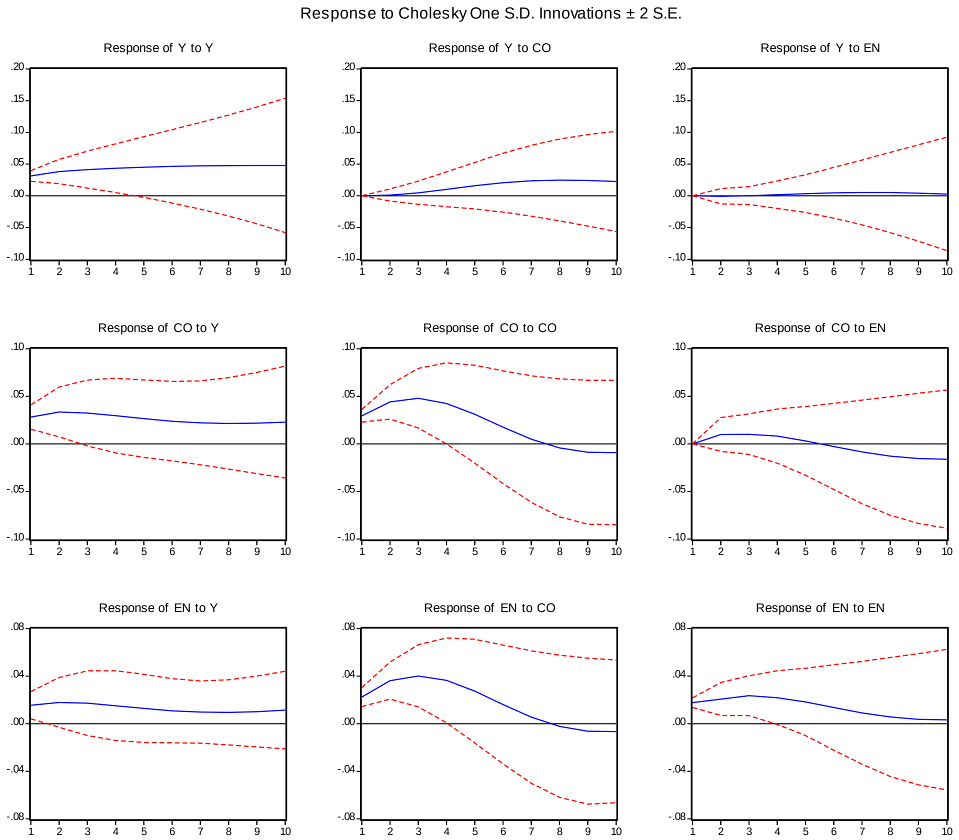
Variance Decomposition and Impulse Response Function

An impulse response function traces the effect of a one standard deviation shock to one of the innovations on current and future values of endogenous variables through the dynamic structure of vector error correction (VEC). A shock to the n-th variable directly affects the n-th variable itself, and is also transmitted to all of the endogenous variables through the dynamic structure of VEC. Cholesky fractionalization approach is commonly used to conduct impulse response analysis. The major limitation of this procedure is that the result varies with the ordering of the variables. Therefore, we apply Generalized Impulses to construct orthogonal set of innovations which does not depend on the order of the VEC.

Table 5: Variance decomposition percentages

Percentage of forecast error variation in	Typical shock in		
	Y	CO	EN
Y	19.1079	14.9029	10.7934
CO	20.6319	19.096	13.0479
EN	17.0201	19.2594	15.8158

Impulse Response



Impulse response functions do not show the magnitude of these relationships between variables. It is not possible to accurately judge the relative strength of different influences on a given variable. Therefore, it is necessary to examine variance decompositions. Variance decompositions show the percentage of forecast error variance for a given variable that can be attributed to each of the explanatory variables including it. In this study, variance decomposition measures the percentage contribution of each innovation to the step ahead forecast error variance of the investment, and provides a means for determining the relative importance of shocks in explaining the variation in investment.

Residual-based short run causality

Dependent Variable	Co-efficient	R-Squared	D.W	F-statistics
Y	0.006128	0.702236	1.403379	34.3054
CO	0.00104	0.763793	1.878425	43.94469
EN	-0.00018	0.749714	1.724301	101.8444

Granger Causality Tests

Pairwise Granger Causality Tests
Sample: 1971 2007
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Probability
CO does not Granger Cause Y	35	1.17802	0.32173
Y does not Granger Cause CO		2.71338	0.08257
EN does not Granger Cause Y	35	0.90828	0.41402
Y does not Granger Cause EN		3.11587	0.05895
EN does not Granger Cause CO	35	1.93021	0.16272
CO does not Granger Cause EN		0.41343	0.66509

Table 5 shows how the variables in the forecast error variance can be broken into components that may be attributed to each of our variables in VAR. Through the innovative shocks, the above approach gives the exact explanation regarding their relationship whereas forecast error variance decomposition of unrestricted VAR (3) models are estimated over a 10-year forecast time horizon as demonstrated by table 5. From the above test, we see that economic growth explains only 14% variation in CO_2 emission and 10% variation in energy consumption. This phenomenon confirms that there is insignificant causal link between economic growth and CO_2 emission and between economic growth and energy consumption.

Figure 1 is the graphical presentation of impulse response function showing how economic growth responds over time to a shock in CO_2 emission and energy consumption.

Table 6 reports the OLS estimates of the residuals. The coefficients of the error terms reveal that there exists no significant causality between economic growth and CO_2 emission and between economic growth and energy consumption.

Conclusions and Policy Implications

This study investigates the causal relationship among CO_2 emission, energy consumption and economic growth in China, one of the largest emitter of CO_2 in the world. Using the most recent time series data for the period of 1976-2010 and employing Johansen cointegration technique and error correction methods, we find cointegrating relationship among the variables economic growth, CO_2 emission and energy consumption. However no causal link is found among the variables. The findings are partially consistent with earlier empirical works on China. Policy makers in China need to further step up its efforts to reduce CO_2 emission in order to avert environmental disasters in near future for the safety of its own future and that of the world.

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