The Impact of Globalization on CO2 Emissions in China

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Abstract: This paper examines the Environmental Kuznets Curve (EKC) hypothesis for China in the presence of globalization. We have applied Bayer and Hanck combined cointegration test as well as the ARDL bounds testing approach to cointegration by accommodating structural breaks in the series. The causal relationship among the variables is investigated by applying the VECM causality framework. The study covers the period of 1970-2012.

The results confirm the presence of cointegration among the variables. Furthermore, the EKC hypothesis is valid in China both in short-and-long runs. Coal consumption increases CO_2 emissions significantly. The overall index and sub-indices of globalization indicate that globalization in China is decreasing CO_2 emissions. The causality results reveal that economic growth causes CO_2 emissions confirming the existence of the EKC hypothesis. The feedback effect exists between coal consumption and CO_2 emissions. CO_2 emissions Granger causes globalization (social, economic and political).

Keywords: China, Coal Consumption, Globalization, CO_2 emissions

I. Introduction

Carbon dioxide emissions have grown dramatically in the past century with rapid economic growth and development. The relationship between environmental quality and economic growth is extensively studied in the existing literature under the environmental Kuznets curve (EKC) hypothesis. The EKC hypothesis posits that at initial stage of economic growth, emissions increase with income. However, as an economy reaches to a threshold level of income per capita, emissions begin to decline with income. This postulated inverted-U shaped relationship between environmental quality and income per capita was first introduced by Grossman and Kruger, (1991). The relationship between energy consumption and economic growth as well as economic growth and environmental pollution has drawn much interest in recent times due to increased awareness of greenhouse gas emissions (GHG) and its impact on the air quality. Kraft and Kraft (1978), in their seminal paper, examined the causal relationship between energy consumption and economic growth for United States and found the causality running from economic growth to energy consumption. The rapid economic growth has been achieved with significant consumption of energy and hence CO_2 emissions have increased. China has increased its coal consumption in recent years and become the largest coal user in the world (Apergis and Payne, 2010).

Coal consumption generates more carbon emissions compared to oil and natural gas. Li et al. (2008) found that coal consumption is the one of the major contributor to CO_2 emissions but one cannot ignore its importance in stimulating economic growth especially in emerging economies like China. China is fulfilling almost 69 percent energy demand from its coal supply. China is both the largest consumer and the largest producer of coal in the world. The tremendous amount of fossil fuels used in energy use also makes China the number one source of GHG emissions in the world and that poses serious environmental concerns. As the development of China continues, the environmental degradation presents significant challenge. However, any attempt to reduce energy consumption will result in declining economic growth in China. If EKC exists for China, large amount of the output will be associated with environmental degradation at early stages of economic development which will later improve and follow an inverted U-shaped curve.

The recent process of globalization of international markets has raised growing concern that the features of the globalization process may jeopardize the environmental sustainability. At the low level of income, environmental degradation tend to rise since people are willing to accept increasing environmental degradation in exchange for higher consumption. However, as individuals achieve higher living standards, they care increasingly about the quality of the environment. Therefore, a long-term correlation between the recent process of globalization of international markets and environmental degradation is quite evident. The globalization of markets also brought about the globalization of environmental problems. Global warming, thinning of the ozone layer, loss of biodiversity, depletion of natural resources, widespread deforestation and desertification are examples of global environmental deterioration that emerged and worsened in the process of globalization.

China has become an increasingly important part of the global trading system over the past two decades. China has adopted one of the developing world’s most open trade and FDI regimes. China achieved a greater degree of openness to foreign trade even prior to WTO accession. The liberalization of trade and FDI regimes has accelerated since late 1990s. The additional openings mandated under China's WTO accession agreement will likely make China's economy the most open of any large developing country. However, Chinese globalization process also brings raising concern of environmental degradation. On the other hand, globalization may also increase per capita income of China and spread the technological knowledge of the most advanced economies, which contributes to reducing environmental degradation intensity in the long run. The process of globalization will push along the rising part of a hypothetical environmental Kuznets curve, i.e. in the direction of diminishing sustainability. However, after a threshold level of per capita income is reached a healthy descent may start and environmental standard will start to improve. In order to clarify to what extent the recent process of globalization has affected Chinese environmental quality; the paper empirically tests the existence of environmental Kuznets curve in China.

The aim of this paper is to examine the validity of EKC hypothesis by incorporating coal consumption and globalization in CO_2 emissions function over the period of 1971-2012 for China. The combined cointegration approach by Bayer and Hanck, (2013) is applied to examine the long run relationship between the variables and robustness of the long run relationship is tested by applying the ARDL bounds testing approach to cointegration in presence of structural breaks in the series. The VECM causality framework is used for detection of direction of causal relationship between the variables. Our results confirm that the variables are cointegrated for long run. The relationship between economic growth and CO_2 emissions is inverted-U shaped i.e. the EKC hypothesis is valid. Coal consumption is contributing factor to CO_2 emissions. Globalization (including economic, social and political consequences) has a negative effect on CO_2 emissions. Moreover, economic growth and globalization Granger causes CO_2 emissions. Coal consumption causes CO_2 emissions in Granger sense.

The remainder of the paper is organized as follows: Section-2 reviews relevant literature; Section-3 describes the data, model construction, and estimation strategy; Section-4 reports and analyses results, and Section-5 offer concluding remark with policy analysis.

II. A Brief Review of Literature

II.1. Economic Growth-Environmental Degradation

The issue of economic growth and environmental degradation has gained importance since mid-90s. There are several studies which discussed the existence of inverted-U shaped relationship between economic growth and environmental degradation. Grossman and Krueger, (1991) started the debate of environmental Kuznets curve (EKC) explaining the relationship between environment pollution and economic development i.e. inverted U-shaped. Selden and Song, (1994) reported that in the initial stages of economic growth, there is positive relationship between economic growth and environmental degradation but after a threshold level, this relationship becomes negative. This implies that economic growth initially deteriorates environmental quality and improves it once economy achieves specific level of income per capita. Similarly, an inverted U-shaped relationship between economic growth and CO_2 emissions is also reported by Heil and Selden, (2001); Vollebergh and Kemfert, (2005) and Galeotti et al. (2006).

The existing empirical literature on the EKC elaborates that how environmental quality of a nation changes when it achieves a sufficient level of wealth. Shafik (1994); Grossman and Krueger (1995); Carson et al. (1997); and Suri, and Chapman (1998) reported that there is an inverted U-shaped relationship between economic growth and environmental degradation during economic development process but Kaufmann et al. (1998) failed to find such relationship between environmental degradation and economic growth. Fried and Getzner, (2003) reported that initially the relationship between economic growth and CO_2 emissions is positive but becomes the N-shaped relationship due to hike in CO_2 emissions with economic growth. Therefore, Spangenberg (2001) argued that the EKC may exist in some cases but not for all. This implies that there is no solid indication of inverted U-shaped relationship between economic growth and environmental degradation. Perman and Stern, (2003) found that the EKC did not exist when being tested by statistical methods. Shahbaz et al. (2013a) examined the relationship between economic growth and CO_2 emissions by incorporating energy consumption in explaining CO_2 emissions using data of Romania. They found the presence of the EKC hypothesis and energy consumption contributes to CO_2 emissions. For Indian economy, Tiwari et al. (2013) also reported that the EKC hypothesis is valid.

Junyi (2006) investigated the validity of the EKC over the period of 1993-2002 using Chinese provincial data. The empirical results found that there is inverted U-shaped relationship between economic growth and energy pollutants; and poor provinces are in need of more financial resources to improve the environmental quality. Liua et al. (2007) confirmed the presence of the EKC theory over the period of 1989-2003 for Shenzhen provincial data. Yaguchi et al. (2007) conducted a comparative study between Japan and China and noted that the EKC hypothesis does exist in case of Japan but same is not true in China. Using solid wastes, waste water and waste gas as indicators of environmental pollution, Song et al. (2008) established an inverted-U shaped relationship between economic growth and pollution emissions in China.

He (2009) tested the validity of the EKC hypothesis for China using annual data from 1992 to 2003. The author reported the validation of the EKC hypothesis and found 10,000 Yuan is threshold level of income per capita. Diao et al. (2009) reinvestigated the relationship between income per capita and environmental quality using performance and economic growth in case of Chinese province Zhejiang. Their results confirmed the presence of EKC theory. Zhang and Cheng (2009) used multivariate model to investigate the causal relationship carbon emissions, energy consumption, urban population and economic growth of China. They found that energy consumption is Granger causes CO_2 emissions and economic growth Granger causes energy consumption. Carbon emissions and energy consumption do not Granger cause economic growth in China.

Li and Li (2011) incorporated coal consumption in energy emissions function in case of China and India over the period of 1965-2006. Their results reported that coal consumption Granger causes economic growth both in India and China. They suggested for efficient technology to reduce CO_2 emissions and to achieve sustainable level of development in both economies. Brajer et al. (2011) also validated the presence of the EKC hypothesis in case of China.

Table-1: Summary of empirical studies in China

Authors	Time Period	Variables	Co-integration	Causality	EKC Hypothesis
Junyi, (2007)	1993-2002	Pollution per capita emission, per capita income	-	-	Yes
Yaguchi et al. (2007)	1975-1995	SO_2 emissions, CO_2 emissions, economic growth	-	-	No
Liua et al. (2007)	1989-2003	Pollution, and economic development	-	-	Yes
Song et al. (2008)	1985-2005	Solid wastes, waste water, waste gas	Yes	-	Yes
He, (2009)	1992-2003	SO_2 emissions, CO_2 emissions, term of trade, income growth	-	-	Yes
Diao et al. (2009)	1995-2005	CO_2 emissions, economic growth	-	-	Yes
Jalil and Mahmud, (2009)	1975-2005	Carbon emission, foreign trade, income, energy consumption	Yes	Unidirectional	Yes
Zhang and Cheng, (2009)	1960-2007	energy consumption, urban population, carbon emissions, economic growth	-	Unidirectional	-
Halkos and Tzeremes, (2011)	1965-2009	Environmental performance, economic development	-	-	No
Li and Li, (2011)	1965-2006	Coal consumption, economic growth	-	Unidirectional	-
Brajer et al. (2011)	-	Pollution, economic development	-	-	Yes
Wang et al. (2011)	1995-2007	energy consumption, carbon emissions,	Yes	$Y \rightarrow E$	-

		economic growth			
Du et al. (2012)	1995-2009	Real GDP per capita, Pollutants per capita, Industrial value added as share of GDP, technological progress, Urbanization	-	-	Yes
Jayanthakumaran et al. (2012)	1972-2007	CO_2 emissions, trade openness, real GDP per capita, energy consumption	Yes	-	Yes
Govindaraju and Tang (2013)	1965-2009	Coal consumption, economic growth, CO_2 emissions	-	$Y \rightarrow E$	-
Guo, (2014)	N.A	Regional income, CO_2 emissions	-	-	Yes
Ren et al. (2014)	2000-2010	Trade, FDI, industrial income per capita, CO_2 emissions			Yes
Shahbaz et al. (2014a)	1971-2011	Coal consumption, industrial income per capita, CO_2 emissions	Yes	$I \rightarrow E$	

Using provincial data, Wang et al. (2011) applied panel causality to examine the relationship between energy consumption, CO_2 emissions and economic growth in China. They found that the variables are cointegrated in the long run and the feedback effect exits between energy consumption and economic growth. Furthermore, economic growth Granger causes CO_2 emissions. Du et al. (2012) used the provincial data and validated the presence of environmental Kuznets curve in China.

Jayanthakumaran et al. (2012) also investigated the relationship between energy consumption, economic growth, CO_2 emissions and trade openness in case of China and India. They reported that the environmental Kuznets curve is validated and energy consumption has positive impact on energy pollutants both in China and India. Trade openness impedes CO_2 emissions in India. Guo, (2014) investigated the environmental Kuznets curve (EKC) hypothesis using regional income and average level of CO_2 emissions. The empirical evidence confirmed the presence of negative relationship between regional income and CO_2 emissions i.e. inverted-U relationship exists. Ren et al. (2014) examined the impact of trade openness, foreign direct investment and economic growth on CO_2 emissions using industrial data over the period of 2000-2010. They noted that trade and foreign direct investment both contribute in CO_2 emissions. Their empirical exercise validated the presence of EKC hypothesis between industrial capita income and CO_2 emissions. Table-1 presents the summary of studies described in review of literature.

II.II. Globalization and Environmental Degradation

Globalization enables the transfer of advanced technology from developed to developing economies, helps in the promotion of division of labor and increases the comparative advantage of different nations. Globalization improves the total factor productivity by increasing trade. It boosts economic activity via foreign direct investment and transfer of advanced technology from developed countries to developing nations. Globalization provides investment opportunities through foreign direct investment and enhances financial markets. Globalization directly enhances trade and economic growth and that influences energy demand and environment. Various researchers have used different measures of globalization to examine its impact on environmental degradation. For instance, Grossman and Krueger, (1991) investigated the environmental impact of NAFTA (Northern America Free Trade Agreement) on environment. They reported that the trade openness (globalization) affects environmental degradation via scale effect while keeping the composition effect and the technique effect constant. Copeland and Taylor, (2004) pointed out that trade depends upon the relative abundance of factor endowment in each country and therefore, comparative advantage of trade also affects environmental quality depending upon trade and environmental policies in the country. Antweiler et al. (2001) and Liddle (2001) pointed out that trade openness improves environmental quality via technique effect. Environmental regulations become strict as income increases and the adoption of energy-efficient technologies are encouraged to save environment from degradation. In case of China; Dean, (2002) reported that trade openness deteriorates environmental quality via improved terms of trade, however, rise in income saves environment from degradation. Magani (2004) used data of 63 developed and developing economies to examine the effect of trade openness on energy emissions. The results showed that a 0.58% of carbon emissions is linked with a 1% increase in trade. Similarly; McAusland, (2008) reported that trade affects environment significantly and same view is confirmed by Frankel, (2009). Similarly, Shahbaz et al. (2013b) reported that trade openness (globalization) positively affects environmental degradation in Indonesian economy.

Shahbaz et al. (2013c) investigated the presence of EKC hypothesis in by incorporating globalization index in CO_2 emissions function for Turkish economy.

III. Economic, Social and Political Aspects of Globalization in China: Our Measure

Globalization enhances interdependence, integration and internationalization. Globalization in China since early 1990s has created a double-edge sword; increased trade, growth and investment activities are the positive aspects. On the other hand, it has created division in the economy with winners and losers. Regions, sectors, social groups are adversely affected due to trade openness are particularly concerned with environmental degradation and CO_2 emissions. Government has taken significant steps in combating emissions in recent years introducing alternative sources of energy, investing in clean coal technology in combination with numerous measures in controlling pollution at the local, state and national level.

Given that major focus of the study is to relate globalization effects on CO_2 emissions, we consider the KOF index of globalization. Dreher, Gaston, and Martens (2008) developed this index of globalization considering three major aspects of globalization individually. We believe, this detailed index is appropriate in measuring globalization effects in China compared to the other measures of the openness. These are economic, social, and political aspects. Economic globalization captures international trade flow of goods, capital, and services. To measure the degree of economic globalization, two indexes are considered. One index includes actual flows of trade, foreign direct and portfolio investment. Income payments to foreign nationals and capital employed are included to proxy for the extent a country employs foreign people and capital in its production processes. The second index includes trade restrictions and capital using hidden import barriers, tariff rates, taxes on international trade, and an index of capital controls.
Political globalization reflects diffusion of government policies and social globalization, expressed as the spread of ideas, information, images, and people. In developing proxy for the degree of political globalization, number of embassies in a country, the number of the United Nations (UN) peace missions a country participated and the number of international organizations to which the country is a member are used. Social globalization is proxied using the flow of information and ideas. For this purpose, information on personal contacts, information flows, and cultural proximity are taken into account. To proxy flows of information and personal contacts international tourism, internet users, and number of radios in a country are used as indicators.

IV. The Data, Model and Estimation Strategy

IV.I. Data

We have used data of coal consumption per capita, CO_2 emissions per capita, real GDP per capita and globalization index to probe the existence of environmental Kuznets curve (EKC) in case of China in presence of globalization. The data on coal consumption (million tons), CO_2 emissions (metric tons) and real GDP (Chinese currency) has been attained from world development indicators (CD-ROM, 2012). The series of population is used to convert all the series into per capita units. The data on KOF globalization index is borrowed from Dreher, (2006). The globalization index is constructed from three sub-indices (social, economic and political globalization[1]). We cover the time period from 1970 to 2012.

[1] See in details http://globalization.kof.ethz.ch/

IV.II. Model

Following Govindaraju and Tang, (2013) and Shahbaz et al. (2013c), we incorporate coal consumption intensity and globalization in CO_2 emissions function as additional determinants of economic growth and hence CO_2 emissions. The general functional form of the model is:

$$E_t = f(C_t, Y_t, Y_t^2, G_t) \tag{1}$$

We have transformed all the variables into natural logarithm. The empirical form of our model is constructed as follows:

$$\ln E_t = \alpha_1 + \alpha_C \ln C_t + \alpha_Y \ln Y_t + \alpha_{Y^2} \ln Y_t^2 + \alpha_G \ln G_t + \mu_t \tag{2}$$

where, $\ln E_t$ is natural log of CO_2 emissions per capita, natural log coal consumption intensity per capita is indicated by $\ln C_t$, $\ln Y_t$ ($\ln Y_t^2$) is natural log of real GDP per capita (square of real GDP per capita) and $\ln G_t$ is for natural log of KOF index of globalization. μ_t is error term assumed to be having normal distribution with zero mean and predictable variance. We expect that impact of coal consumption on CO_2 emissions is positive and $\alpha_C > 0$. The relationship between economic growth and CO_2 emissions inverted U-shaped if $\alpha_Y > 0$ and $\alpha_{Y^2} < 0$ otherwise U-shaped if $\alpha_Y < 0$ and $\alpha_{Y^2} > 0$. $\alpha_G < 0$ if energy-efficient technology via foreign direct investment and trade is encouraged for domestic production otherwise $\alpha_G > 0$.

IV.III. Estimation Steps

IV.III.I Zivot-Andrews Unit Root Test

Numerous unit root tests are available to test the stationarity properties of the variables including ADF by Dickey and Fuller (1979), P-P by Phillips and Perron (1988), KPSS by Kwiatkowski et al. (1992), DF-GLS by Elliott et al. (1996) and Ng-Perron by Ng-Perron (2001). These tests provide biased and spurious results due to non-availability of information about structural break points in series. In doing so, Zivot-Andrews (1992) developed three models to test the stationarity properties of the variables in the presence of structural break point in the series: (i) this model allows a one-time change in variables at level form, (ii) this model permits a one-time change in the slope of the trend component i.e. function and (iii) model has one-time change both in intercept and trend function of the variables to be used for empirical analysis. Zivot-Andrews (1992) followed three models to validate the hypothesis of one-time structural break in the series as follows:

$$\Delta x_t = a + ax_{t-1} + bt + cDU_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \tag{3}$$

$$\Delta x_t = b + bx_{t-1} + ct + bDT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \tag{4}$$

$$\Delta x_t = c + cx_{t-1} + ct + dDU_t + dDT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \tag{5}$$

where dummy variable is indicated by DU_t showing mean shift occurred at each point with time break while trend shift variables is show by DT_t. So,

$$DU_t = \begin{cases} 1 \ldots if \quad t > TB \\ 0 \ldots if \quad t < TB \end{cases} \text{ and } DU_t = \begin{cases} t - TB \ldots if \;\; t > TB \\ 0 \ldots if \;\; t < TB \end{cases}$$

The null hypothesis of unit root break date is $c = 0$ which indicates that series is not stationary with a drift not having information about structural break point while $c < 0$ hypothesis implies that the variable is found to be trend-stationary with one unknown time break. Zivot-Andrews unit root test fixes all points as potential for possible time break and estimates through regression for all possible break points successively. Then, this unit root test selects that time break which decreases one-sided t-statistic to test $\hat{c}(= c - 1) = 1$. Zivot-Andrews report that in the presence of end points, asymptotic distribution of the statistics is diverged to infinity point. It is necessary to choose a region where end points of sample period are excluded. Further, Zivot-Andrews suggested the trimming regions i.e. (0.15T, 0.85T).

IV.III.II Bayer and Hanck Cointegration Approach

In econometric analysis, for time series data it is said to be integrated if two or more series are individually integrated, but some linear combination of them has a lower order of integration. Engle and Granger, (1987) formalized the first approach of cointegration test which is a necessary criteria for stationarity among non-stationary variables. This approach provides more powerful tools when the data sets are of limited length as most economic time-series are. Later, another cointegration test called Johansen maximum eigen value test was developed by Johansen (1991). Since it permits more than one cointegrating relationship, this test is more generally applicable than Engle–Granger test. Another main approach of cointegration testing of which its technique is based on residuals is Phillips–Ouliaris cointegration test developed by Phillips and Ouliaris (1990). Other important approaches include the Error Correction Model (ECM) based F-test of Peter Boswijk (1994), and ECM based t-test of Banerjee et al. (1998).

However, different tests might suggest different conclusions. To enhance the power of cointegration test, with the unique aspect of generating a joint test-statistic for the null of no-cointegration based on Engle and Granger, Johansen, Peter Boswijk, and Banerjee tests, the so called Bayer-Hanck combined test was newly proposed by Bayer and Hanck (2013). Since this new approach allows us to combine various individual cointegration test results to provide a more conclusive finding, it is also applied in this paper to check the presence of cointegrating relationship among economic growth, coal consumption, globalization and CO_2 emissions in case of China. Following Bayer and Hanck (2013), the combination of computed significance level (p-value) of individual cointegration test in this paper is in Fisher's formulas as follows:

$$EG - JOH = -2\left[\ln(p_{EG}) + (p_{JOH})\right] \tag{6}$$

$$EG - JOH - BO - BDM = -2\left[\ln(p_{EG}) + (p_{JOH}) + (p_{BO}) + (p_{BDM})\right] \tag{7}$$

Where p_{EG}, p_{JOH}, p_{BO} and p_{BDM} are the *p*-values of various individual cointegration tests respectively. It is assumed that if the estimated Fisher statistics exceed the critical values provided by Bayer and Hanck (2013), the null hypothesis of no cointegration is rejected.

IV.III.III The VECM Granger Causality

After examining the long run relationship between the variables, we use the Granger causality test to determine the causality between the variables. If there is cointegration between the series then the vector error correction method (VECM) can be developed as follows:

$$(1-L)\begin{bmatrix} \ln E_t \\ \ln Y_t \\ \ln Y_t^2 \\ \ln C_t \\ \ln G_t \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} + \begin{bmatrix} b_{11i}\, b_{12i}\, b_{13i}\, b_{14i}\, b_{15i} \\ b_{21i}\, b_{22i}\, b_{23i}\, b_{24i}\, b_{25i} \\ b_{31i}\, b_{32i}\, b_{33i}\, b_{43i}\, b_{53i} \\ b_{41i}\, b_{42i}\, b_{43i}\, b_{44i}\, b_{45i} \\ b_{51i}\, b_{52i}\, b_{53i}\, b_{54i}\, b_{55i} \end{bmatrix} \times \begin{bmatrix} \ln E_{t-1} \\ \ln Y_{t-1} \\ \ln Y_{t-1}^2 \\ \ln C_{t-1} \\ \ln G_{t-1} \end{bmatrix} + .. + \begin{bmatrix} b_{11i}\, b_{12i}\, b_{13i}\, b_{14i}\, b_{15i} \\ b_{21i}\, b_{22i}\, b_{23i}\, b_{24i}\, b_{25i} \\ b_{31i}\, b_{32i}\, b_{33i}\, b_{43i}\, b_{53i} \\ b_{41i}\, b_{42i}\, b_{43i}\, b_{44i}\, b_{45i} \\ b_{51i}\, b_{52i}\, b_{53i}\, b_{54i}\, b_{55i} \end{bmatrix}$$
$$\times \begin{bmatrix} \ln E_{t-1} \\ \ln Y_{t-1} \\ \ln Y_{t-1}^2 \\ \ln C_{t-1} \\ \ln G_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha \\ \beta \\ \delta \\ \phi \\ \vartheta \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix} \qquad (8)$$

where difference operator is $(1-L)$ and ECM_{t-1} is the lagged error correction term, generated from the long run association. The long run causality is found by significance of coefficient of lagged error correction term using t-test statistic. The existence of a significant relationship in first differences of the variables provides evidence on the direction of short run causality. The joint χ^2 statistic for the first differenced lagged independent variables is used to test the direction of short-run causality between the variables. For example, $B_{12,i} \neq 0 \forall_i$ shows that economic growth Granger causes CO_2 emissions and CO_2 emissions is Granger cause economic growth if $B_{11,i} \neq 0 \forall_i$.

V. Findings and Discussions

For investigating the cointegration among the variables, testing the stationarity of the variables is necessary condition. For this purpose, we apply Augmented Dicky-Fuller (ADF) and Philip Perron (PP) unit root tests with intercept and trend. The results are reported in Table-2. We find that CO_2 emissions per capita, real GDP per capita (squared of real GDP per capita), coal consumption per capita, globalization (economic globalization, political globalization and social globalization) are found non-stationary at level. ADF and PP tests show in Table-2 that all the variables are integrated at I(1).

Table-2: Unit Root Analysis

Variable	ADF Unit Root Test		P-P Unit Root Test	
	t- statistic	Prob. value	t- statistic	Prob. value
$\ln E_t$	-2.2795 (2)	0.4343	-1.9487 (3)	0.6115
$\ln Y_t$	-3.1343 (1)	0.1360	-3.4000 (3)	0.0653
$\ln Y_t^2$	-2.1808 (2)	0.4808	-2.5580 (3)	0.3008
$\ln C_t$	2.5988 (1)	0.2830	2.5434 (6)	0.3069
$\ln G_t$	-1.1909 (1)	0.8989	-1.3366 (3)	0.8661
$\ln EG_t$	-2.0343 (3)	0.5653	-2.9902 (3)	0.5603
$\ln PG_t$	-1.8647 (2)	0.6539	-1.9765 (6)	0.5964
$\ln SG_t$	-1.6210 (2)	0.7667	1.8908 (3)	0.6410
$\Delta \ln E_t$	-4.0880 (2)**	0.0136	-4.4714 (3)*	0.0050
$\Delta \ln Y_t$	-4.3742 (1)*	0.0071	-4.4126 (3)*	0.0059
$\Delta \ln Y_t^2$	-3.8384 (2)**	0.0251	-4.2013 (3)**	0.0101
$\Delta \ln C_t$	-4.3486 (1)*	0.0071	-6.0807 (3)*	0.0001
$\Delta \ln G_t$	-3.9767 (1)**	0.0179	-6.2928 (3)*	0.0000
$\Delta \ln EG_t$	-4.3234 (1)*	0.0075	-5.2333 (3)*	0.0006
$\Delta \ln PG_t$	-3.8628 (2)**	0.0235	-5.7411 (3)*	0.0001
$\Delta \ln SG_t$	-4.4242 (3)*	0.0058	-6.0002 (3)*	0.0001
Note: * and ** indicates significant at 1% and 5% levels of significance. Lag length of variables is shown in small parentheses.				

ADF and PP unit root test provide ambiguous due to their low explanatory power. These unit root tests do not accommodate information about unknown structural break dates stemming the series which further weakens the stationarity hypothesis. To resolve this issue, we have applied Zivot-Andrews unit root test which accommodates the information about single unknown structural break arising in the series. The results of Zivot-Andrews structural break are presented in Table-3. We find that all the variables have unit root problem at level in the presence of structural breaks. The structural breaks i.e. 2006, 1980 (1991), 2006, 2002, 1995, 2004 and 2000 are found in the series of CO_2 emissions, real GDP per capita (squared of real GDP per capita), coal consumption per capita, globalization, economic globalization, political globalization and social globalization. We note that all the variables are stationary in their first differenced form. This indicates that all the series are integrated at I(1).

Table-3: Zivot-Andrews Structural Break Trended Unit Root Test

Variable	**At Level**		**At 1st Difference**	
	T-statistic	Time Break	T-statistic	Time Break
$\ln E_t$	-4.212 (1)	2006	-5.670 (2)*	2005
$\ln Y_t$	-3.402 (1)	1980	-4.995 (1)**	1985
$\ln Y_t^2$	-2.929 (2)	1991	-4.541 (1)**	1985

$\ln C_t$	-2.808 (1)	2006	-6.471 (2)**	2004
$\ln G_t$	-2.249 (2)	2002	-7.761 (1)*	1991
$\ln EG_t$	-3.237 (3)	1995	-6.109 (2)*	1982
$\ln PG_t$	-2.422 (2)	2004	-6.829 (1)*	1991
$\ln SG_t$	-2.445 (1)	2000	-6.289 (2)*	1991
Note: * and ** indicates significant at 1% and 5% levels of significance. Lag length of variables is shown in small parentheses.				

All the unit root tests show that the variables are stationary at first difference i.e. $I(1)$. In such situation, the combined cointegration tests developed by Bayer and Hanck, (2013) are suitable to examine whether cointegration exists among the variables. Table-4 illustrates the combined cointegration tests including the EG-JOH, and EG-JOH-BO-BDM. We find that Fisher-statistic for EG-JOH and EG-JOH-BO-BDM tests exceed the critical values at 5% level of significance once we used CO_2 emissions and coal consumption as dependent variables. This rejects the null hypothesis of no cointegration among the variables. The similar results are found once we used economic globalization, political globalization and social globalization as measure of globalization. This confirms the cointegration among the variables. We may conclude that there is long run relationship between CO_2 emissions per capita, real GDP per capita (squared of real GDP per capita), coal consumption per capita, globalization (economic globalization, political globalization and social globalization) over the period of 1970-2012 in the case of China

Table-4: The Results of Bayer and Hanck Cointegration Analysis

Estimated Models	EG-JOH	EG-JOH-BO-BDM	Cointegration
$E_t = f(Y_t, Y_t^2, C_t, G_t)$	19.9180**	28.9417**	Yes
$Y_t = f(E_t, Y_t^2, C_t, G_t)$	4.9220	4.7595	No
$Y_t^2 = f(E_t, Y_t, C_t, G_t)$	4.5443	7.1298	No
$C_t = f(CO_t, Y_t, Y_t^2, G_t)$	16.6515**	30.3088**	Yes
$G_t = f(E_t, Y_t, Y_t^2, C_t)$	5.2869	8.5891	No
$E_t = f(Y_t, Y_t^2, C_t, EG_t)$	14.2517**	21.7463**	Yes
$Y_t = f(E_t, Y_t^2, C_t, EG_t)$	4.4047	4.0684	No
$Y_t^2 = f(E_t, Y_t, C_t, EG_t)$	3.2393	9.916	No
$C_t = f(E_t, Y_t, Y_t^2, EG_t)$	13.4417**	23.2833**	Yes
$EG_t = f(E_t, Y_t, Y_t^2, C_t)$	5.3770	19.2336	No
$E_t = f(Y_t, Y_t^2, C_t, SG_t)$	19.6515**	29.7104**	Yes
$Y_t = f(E_t, Y_t^2, C_t, SG_t)$	4.8971	6.9295	No
$Y_t^2 = f(E_t, Y_t, C_t, SG_t)$	4.0006	23.7784	No
$C_t = f(E_t, Y_t, Y_t^2, SG_t)$	17.9264**	27.3033**	Yes
$SG_t = f(E_t, Y_t, Y_t^2, C_t)$	6.0862	14.5402	No
$E_t = f(Y_t, Y_t^2, C_t, PG_t)$	18.8359**	25.4946**	Yes
$Y_t = f(E_t, Y_t^2, C_t, SG_t)$	5.8048	14.2255	No

$Y_t^2 = f(E_t, Y_t, C_t, PG_t)$	5.5607	12.5951	No
$C_t = f(E_t, Y_t, Y_t^2, PG_t)$	20.3743**	32.6204**	Yes
$PG_t = f(E_t, Y_t, Y_t^2, C_t)$	7.4769	9.7312	No
Note: ** represents significant at 5 per cent level. Critical values at 5% level are 10.576 (EG-JOH) and 20.143 (EG-JOH-BO-BDM) respectively.			

Table-5: The Results of ARDL Cointegration Test

Bounds Testing to Cointegration				Diagnostic tests			
Estimated Models	Optimal lag length	Structural Break	F-statistics	χ^2_{NORMAL}	χ^2_{ARCH}	χ^2_{RESET}	χ^2_{SERIAL}
$CO_t = f(Y_t, Y_t^2, C_t, G_t)$	2, 1, 2, 2, 2	2002	8.087*	0.6909	[1]: 2.6045	[1]: 0.1331	[2]: 2.6710
$Y_t = f(CO_t, Y_t^2, C_t, G_t)$	2, 2, 2, 2, 2	1980	3.021	1.2402	[2]: 3.1366	[2]: 2.8165	[1]: 0.0003
$Y_t^2 = f(CO_t, Y_t, C_t, G_t)$	2, 2, 2, 1, 2	1991	3.367	1.4054	[1]: 0.0615	[2]: 4.0109	[2]: 0.0027
$C_t = f(CO_t, Y_t, Y_t^2, G_t)$	2, 2, 2, 1, 2	2006	5.619**	0.1448	[1]: 0.0041	[2]: 1.453	[1]: 1.5558
$G_t = f(CO_t, Y_t, Y_t^2, C_t)$	2, 1, 2, 1, 1	2002	2.486	0.1804	[1]: 0.5618	[1]: 1.1652	[1]: 3.9091
$CO_t = f(Y_t, Y_t^2, C_t, EG_t)$	2, 2, 2, 2, 2,	2002	9.918*	0.2835	[1]: 0.4272	[1]: 0.6906	[1]: 4.9323
$Y_t = f(CO_t, Y_t^2, C_t, EG_t)$	2, 2, 1, 2, 1	1980	3.956	0.2825	[1]: 3.4186	[1]: 3.406	[1]: 0.6177
$Y_t^2 = f(CO_t, Y_t, C_t, EG_t)$	2, 2, 2, 1, 2	1991	3.079	0.3500	[1]: 1.4042	[1]: 4.0426	[4]: 0.9442
$C_t = f(CO_t, Y_t, Y_t^2, EG_t)$	2, 2, 1, 2, 2	2006	6.218*	1.1964	[2]: 0.0126	[3]: 0.5482	[3]: 3.6632
$EG_t = f(CO_t, Y_t, Y_t^2, C_t)$	2, 2, 2, 1, 1,	1995	2.640	1.6304	[1]: 0.3464	1]: 1.5894	[1]: 5.1991
$CO_t = f(Y_t, Y_t^2, C_t, SG_t)$	2, 1, 2, 1, 2	2002	9.066*	0.2214	[1]: 0.2009	[1]: 1.2695	[3]: 4.8617
$Y_t = f(CO_t, Y_t^2, C_t, SG_t)$	2, 2, 1, 1, 2	1980	2.891	0.3346	[1]: 2.2695	[1]: 3.6889	[2]: 2.7590
$Y_t^2 = f(CO_t, Y_t, C_t, SG_t)$	2, 2, 1, 1, 1	1991	3.726	0.5533	[1]: 0.2019	[2]: 0.8778	[1]: 4.7600
$C_t = f(CO_t, Y_t, Y_t^2, SG_t)$	2, 2, 2, 2, 1	2006	6.078*	0.1372	[1]: 0.3896	[4]: 0.5574	[1]: 1.2730
$SG_t = f(CO_t, Y_t, Y_t^2, C_t)$	2, 1, 2, 1, 1	2000	3.489	3.2016	[2]: 2.1182	[4]: 2.5852	[1]: 0.4545
$CO_t = f(Y_t, Y_t^2, C_t, PG_t)$	2, 1, 1, 2, 2	2002	6.431*	0.1369	[1] 0.4422	[2]: 0.5852	[1]: 0.4545
$Y_t = f(CO_t, Y_t^2, C_t, SG_t)$	2, 2, 2, 2, 2	1980	4.571	1.8663	[2]: 0.1608	[2]: 2.4939	[1]: 0.0005
$Y_t^2 = f(CO_t, Y_t, C_t, PG_t)$	2, 2, 2, 2, 1	1991	2.540	3.9719	[1]: 4.1661	[4]: 0.4882	[1]: 1.0008
$C_t = f(CO_t, Y_t, Y_t^2, PG_t)$	2, 1, 1, 2, 2	2006	5.561**	1.2058	[2]: 1.0052	[1]: 0.6269	[1]: 0.5554
$PG_t = f(CO_t, Y_t, Y_t^2, C_t)$	2, 2, 2, 1, 1	2004	2.350	1.9231	[2]: 3.9787	[1]: 2.6241	[2]: 2.7288
	Critical values (T= 42)[#]						
	Lower bounds $I(0)$	Upper bounds $I(1)$					
	6.053	7.458					
	4.450	5.560					

	3.740	4.780					
Note: The asterisks * and ** denote the significant at 1 and 5 per cent levels, respectively. The optimal lag length is determined by AIC. [ ] is the order of diagnostic tests. # Critical values are collected from Narayan, (2005).							

Bayer and Hanck, (2013) combined cointegration approach provides efficient empirical results but fails to accommodate structural breaks while investigating the cointegration between the variables. This issue is solved by applying the ARDL bounds testing approach to cointegration in the presence of structural breaks following Shahbaz et al. (2014 b, c). The ARDL bounds test is sensitive to lag length selection and we have used the AIC criteria to select appropriate lag order of the variables. It is reported by Lütkepohl, (2006) that the dynamic link between the series can be captured if appropriate lag length is chosen (Lütkepohl, 2006). The results are reported in column-2, Table-5. We use critical bounds from Narayan, (2005) to make decision either cointegration exists or not. Our results show that in our calculated F-statistic is greater than upper bound bounds as we used CO_2 emissions (E_t) and coal consumption (C_t) as dependent variables. The similar results are also found when we used other measures of globalization (economic globalization, political globalization and social globalization). This shows that the ARDL bounds testing analysis confirms our established long run among the series (See Table-5)

After finding the cointegration among the variables, we examine the long run and short run impact of economic growth, coal consumption and globalization on CO_2 emissions. The long run results are presented in Table-6. We find that there is positive and negative relationship of real GDP per capita and squared real GDP per capita with CO_2 emissions. It is statistically at 1 percent level of significant. This indicates that a 1% rise in real GDP will raise CO_2 emissions by 2.56% while negative sign of squared term seems to corroborate the delinking of CO_2 emissions and real GDP at the higher level of income. It confirms the presence of EKC hypothesis in case of China. These findings are consistent with Junyi (2007), Liua et al. (2007), Song et al. (2008), He (2009), Diao et al. (2009), Jalil and Mahmud (2009), Brajer et al. (2011), Du et al. (2012) and Jayanthakumaran et al. (2012) in case of China. Shahbaz et al. (2012), Shahbaz et al. (2013a, b, c), Tiwari et al. (2013) and Shahbaz et al. (2014b, c) in case of Pakistan, Turkey, Romania, Indonesia, India, Bangladesh and Tunisia respectively. Coal consumption positively and significantly affects CO_2 emissions at 1 per cent level of significance. A 0.7317 per cent increase in CO_2 emissions is linked with 1 percent increase in coal consumption, all else is same. This finding is consistent with Govindaraju and Tang (2013) and Tiwari et al. (2013) in case of China and India respectively. The negative relationship between globalization (economic globalization, social globalization and political globalization) and CO_2 emissions exits and it is statistically significant at 1 per cent and 10 per cent levels respectively. Keeping other things constant, a 1 per cent increase in globalization (economic globalization, social globalization and political globalization) will lower CO_2 emissions by 0.5519 per cent (0.8371, 0.2092 and 0.3017). This shows that globalization declines CO_2 emissions via income effect, scale effect and technique effect. Further, this confirms the affectivity and concern of Chinese government to lowering CO_2 emissions by adopting environmental policies with rapid economic growth[2].

[2] This confirms the findings reported by Shahbaz et al. (2013c, 2015) who noted that globalization improves environmental quality in Turkey and India via income, scale and technique effects.

Table-6: Long and Short-Run Analysis

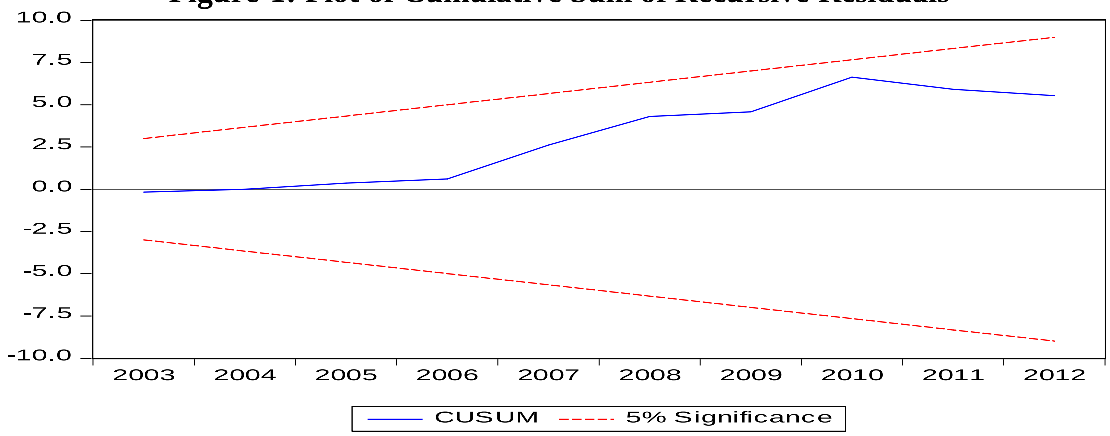
Dependent Variable = $\ln E_t$								
Long Run Results								
Variable	Model 1		Model 2		Model 3		Model 4	
	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic
Constant	-9.4607*	-5.9136	-12.3384*	-6.5138	-8.1357*	-5.4091	-7.3961*	-4.6053
$\ln Y_t$	2.5627*	6.5094	3.3199*	6.7531	2.0011*	5.9890	2.0925*	4.8868
$\ln Y_t^2$	-0.1232*	-5.9736	-0.1594*	-6.5473	-0.0951*	-5.0024	-0.1064*	-4.5443
$\ln C_t$	0.7317*	6.9450	0.6141*	6.0812	0.6821*	6.4911	0.8005*	6.7062
$\ln G_t$	-0.5519*	-3.3135	…	…	…	…	…	…
$\ln EG_t$	…	…	-0.8371*	-3.9122	…	…	…	…
$\ln SG_t$	…	…	…	…	-0.2092*	-3.1821	…	…
$\ln PG_t$	…	…	…	…			-0.3017***	-1.8055
Short Run Analysis								
Constant	0.0264	0.6355	0.0197	0.5234	0.0220	0.5375	0.0327	0.9969
$\Delta \ln Y_t$	1.9487***	1.8705	2.4736**	2.0129	2.0857***	1.9459	1.9927***	1.8876
$\Delta \ln Y_t^2$	-0.1143***	-1.8217	-0.1394**	-2.0604	-0.1215***	-1.9630	-0.1204***	-1.8115
$\Delta \ln C_t$	0.2782*	3.2521	0.3090*	3.3557	0.2870*	3.1313	0.2708*	3.8626
$\Delta \ln G_t$	-0.0048	-0.0189	…	…	…	…	…	…
$\Delta \ln EG_t$	…	…	-0.0961	-0.5566	…	…	…	…
$\Delta \ln SG_t$	…	…	…	…	0.0514	0.6385	…	…
$\Delta \ln PG_t$	…	…	…	…	…	…	-0.0686	-0.2340
ECM_{t-1}	-0.2555**	-2.2435	-0.3889*	-3.0624	-0.2643***	-1.9909	-0.2321**	-2.2968
Diagnostic Tests								
Test	F-statistic	Prob.value	F-statistic	Prob.value	F-statistic	Prob.value	F-statistic	Prob.value
χ^2 *NORMAL*	0.9665	0.6170	0.1363	0.9340	1.4794	0.47772	0.6463	0.7238
χ^2 *SERIAL*	1.9866	0.1094	1.611	0.1586	1.3782	0.2502	1.7792	0.1099
χ^2 *ARCH*	0.5700	0.4550	0.9752	0.3297	1.9432	0.1716	2.2872	0.1161
χ^2 *WHITE*	1.2489	0.3081	1.4806	0.2024	1.2016	0.3347	1.7210	0.1289
χ^2 *RAMSEY*	0.0488	0.8266	0.0020	0.9642	0.0045	0.9467	0.0148	0.9038
Note: *, ** and *** indicate significance at 1%, 5% and 10% levels respectively.								

The short run results are also shown in lower segment of Table-6. We find that the EKC hypothesis is validated and it is statistically significant. The impact of coal consumption is positive on CO_2 emissions and significant at 1 per cent level. The relationship between globalization and CO_2 emissions is negative but statistically insignificant. The negative and statistically significant estimates for each of ECM_{t-1}, -0.2555, -0.3889, -0.2643 and -0.2321 (for overall globalization, economic globalization, social globalization and political globalization models, respectively) lend support to long run relationship among the series in case of China. The coefficients are all statistically significant at 5, 1, 10 and 5% levels respectively. The short run deviations from the long run equilibrium are corrected by 25.55%, 38.89%, 26.43% and 23.21% towards long run equilibrium path each year. The diagnostic tests show that error terms of short run models are normally distributed; and free of serial correlation, heteroskedasticity, and ARCH problems in all three models. The Ramsey reset test shows that functional form for the short run models is well specified.

The test conducted by the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMsq) suggests stability of the long and short run parameters (Figs. 1–8). The graphs of CUSUM which confirm stability of parameters (Brown et al. 1975) but and CUSUMsq test does not lie within the 5% critical bounds. The plots of the CUSUMsq of squares statistics are not well within the critical bounds. We find that graphs of CUSUM and CUSUMsq are within critical bounds at 5 percent level of significance. This ensures the stability of long run and short run coefficients[3].

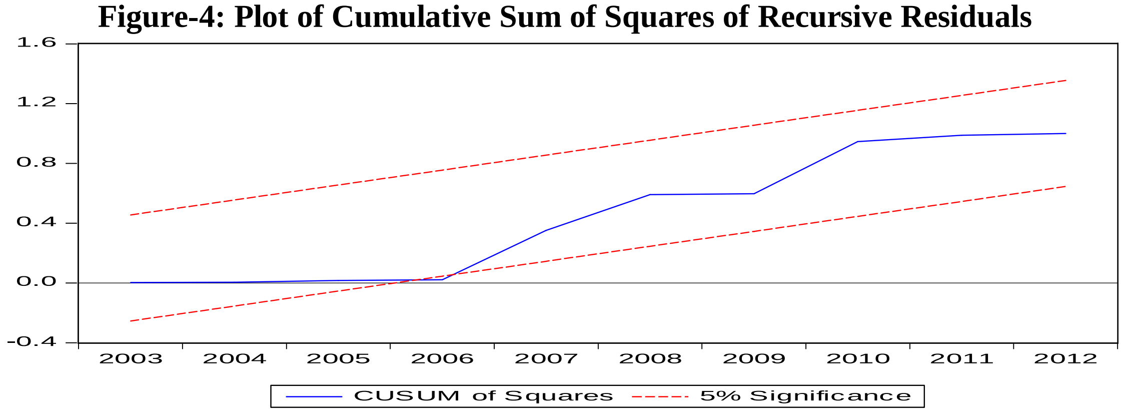
Overall Globalization Model

Figure-1: Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Figure-4: Plot of Cumulative Sum of Squares of Recursive Residuals

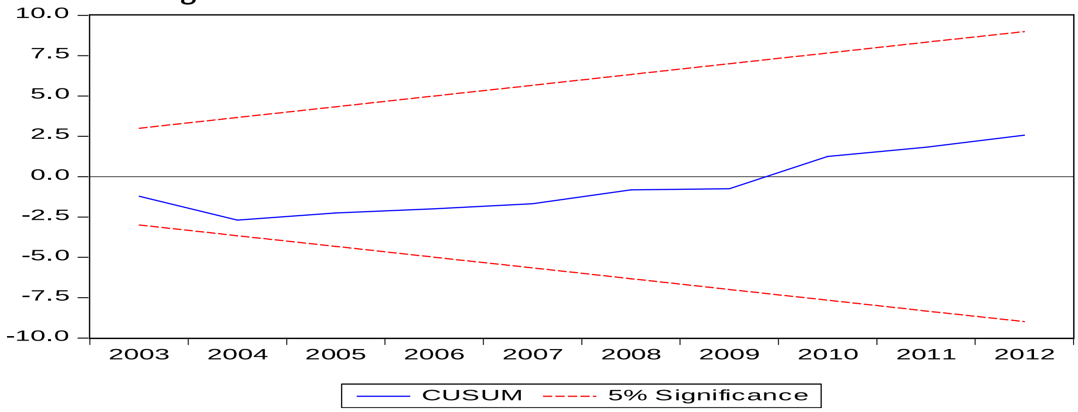


The straight lines represent critical bounds at 5% significance level

[3] The CUSUMsq test shows legible deviation but overall Figure-4 confirms the stability of long-run and short-run estimates.

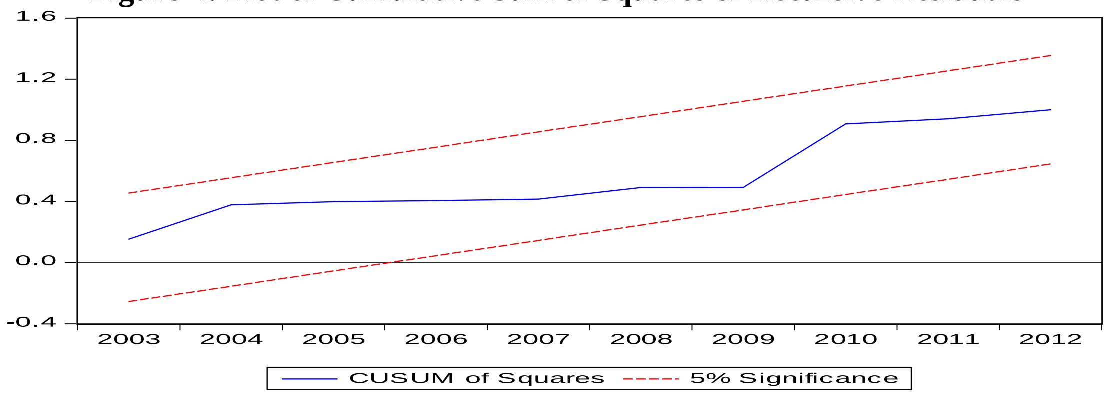
Economic Globalization Model

Figure-3: Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

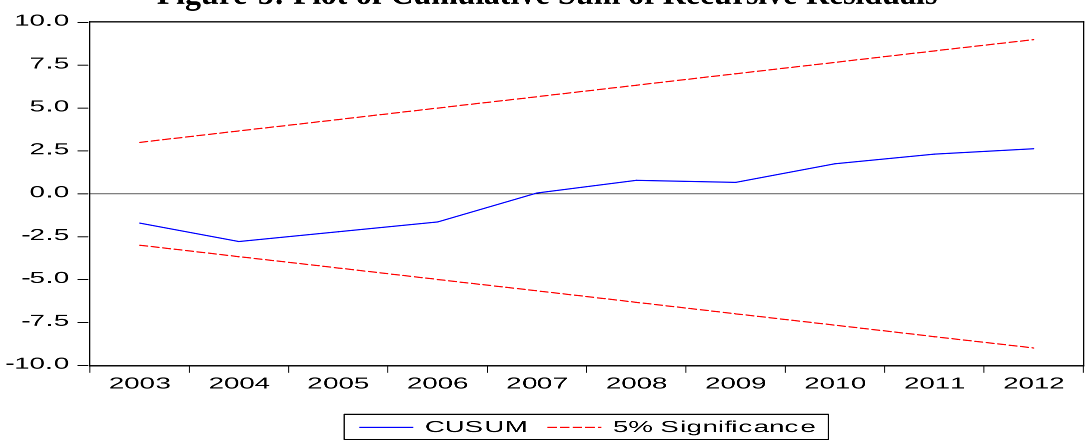
Figure-4: Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

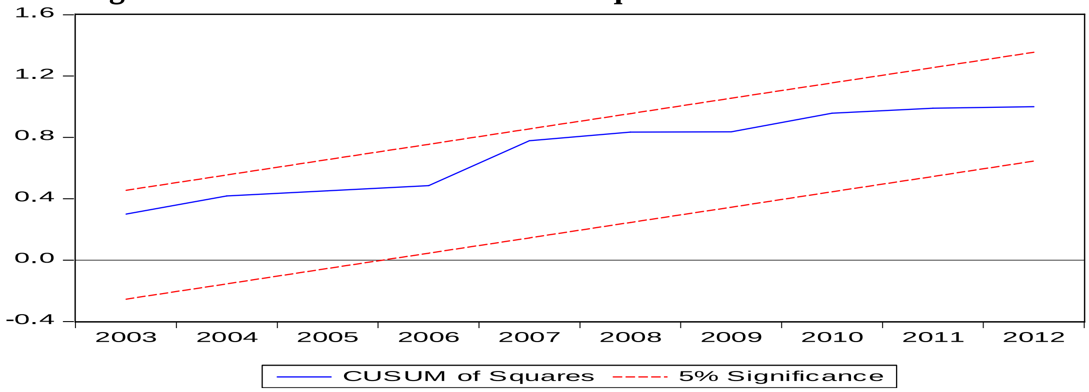
Social Globalization Model

Figure-5: Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

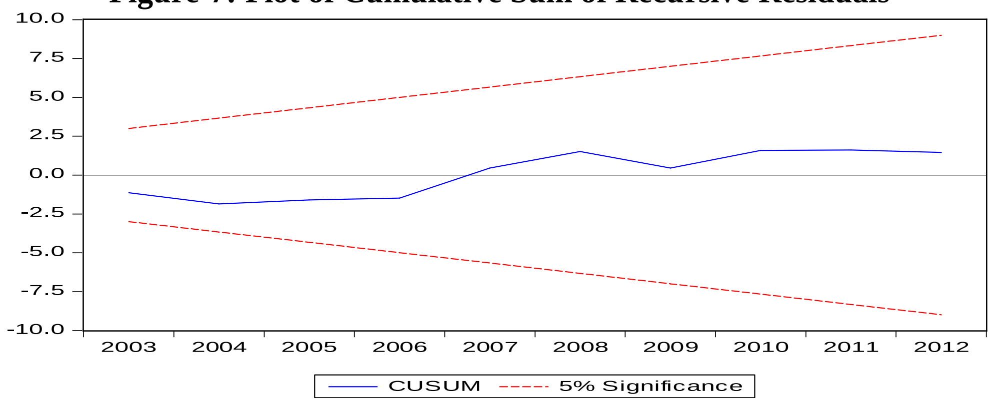
Figure-6: Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

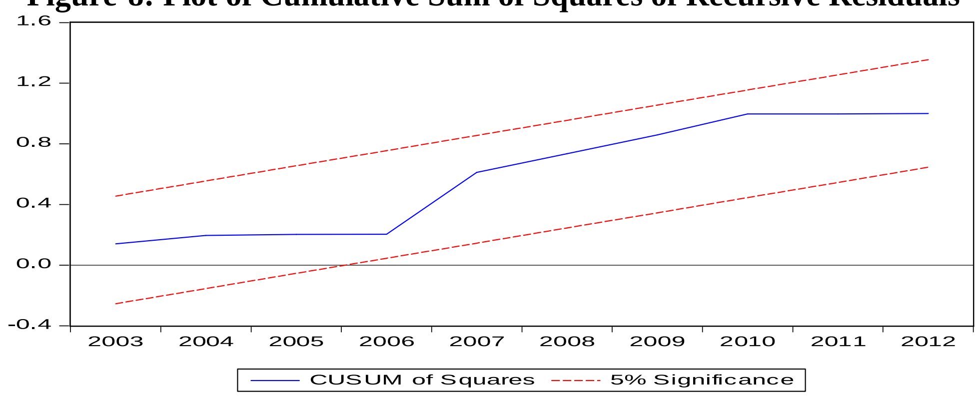
Political Globalization Model

Figure-7: Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Figure-8: Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

The VECM Granger Causality Analysis

If cointegration is confirmed, there must be uni- or bidirectional causality among the series. We examine this relation within the VECM framework. Such knowledge is helpful in crafting appropriate energy policies for sustainable economic growth. Table-7 reports results on the direction of long and short run causality. The results suggest the feedback relationship between coal consumption and CO_2 emissions. The unidirectional causality is found running from economic globalization, social globalization, political globalization and overall globalization to coal consumption. Economic growth Granger causes CO_2 emissions. This finding further supports to the existence of environmental Kuznets curve in China (see Shahbaz, 2013, Shahbaz and Leitão, 2013). Coal consumption is cause of economic growth in Granger sense. The causality running from coal consumption, globalization (economic globalization, social globalization and political globalization) to CO_2 emissions economic growth supports the coal consumption-led- CO_2 emissions and globalization (economic globalization, social globalization and political globalization)-led- CO_2 emissions hypotheses.

Table-7: VECM Granger Causality Analysis

Dependent Variable	Type of causality					
	Short Run					Long Run
	$\sum \Delta \ln E_{t-1}$	$\sum \Delta \ln Y_{t-1}$	$\sum \Delta \ln Y_{t-1}^2$	$\sum \Delta \ln C_{t-1}$	$\sum \Delta \ln EG_{t-1}$	ECT_{t-1}
$\Delta \ln E_t$	…	0.7374 [0.4874]	0.4766 [0.6258]	4.6519** [0.0180]	0.8683 [0.4306]	-0.6721* [-4.2267]
$\Delta \ln Y_t$	1.4925 [0.2416]	…	15.7683* [0.0000]	2.1255 [0.1376]	0.2280 [0.7975]	…
$\Delta \ln Y_t^2$	1.4994 [0.2401]	16.8746* [0.0000]	…	2.1154 [0.1138]	0.2325 [0.7940]	…
$\Delta \ln C_t$	2.4903*** [0.1008]	0.1323 [0.8667]	0.1298 [0.8787]	…	0.6846 [0.5125]	-0.5606* [-3.2610]
$\Delta \ln EG_t$	0.0603 [0.9415]	1.7891 [0.1851]	1.3258 [0.2812]	0.7559 [0.4586]	…	…
	$\sum \Delta \ln E_{t-1}$	$\sum \Delta \ln Y_{t-1}$	$\sum \Delta \ln Y_{t-1}^2$	$\sum \Delta \ln C_{t-1}$	$\sum \Delta \ln SG_{t-1}$	
$\Delta \ln E_t$	…	0.3465 [0.7101]	0.5293 [0.5955]	8.9128* [0.0012]	0.1514 [0.8602]	-0.5085*** [-2.0259]
$\Delta \ln Y_t$	1.1759 [0.3244]	…	12.0740* [0.0000]	1.6224 [0.2168]	0.4850 [0.6211]	…
$\Delta \ln Y_t^2$	1.1408 [0.3350]	18.8482* [0.0000]	…	1.4915 [0.2436]	0.6353 [0.5377]	…
$\Delta \ln C_t$	1.5061 [0.2412]	0.7310 [0.4914]	1.1267 [0.3400]	…	2.1783 [0.1343]	-0.5986* [-3.4020]
$\Delta \ln SG_t$	0.6078 [0.5521]	0.5361 [0.5914]	0.5565 [0.5799]	1.0363 [0.3689]	…	…
	$\sum \Delta \ln E_{t-1}$	$\sum \Delta \ln Y_{t-1}$	$\sum \Delta \ln Y_{t-1}^2$	$\sum \Delta \ln C_{t-1}$	$\sum \Delta \ln PG_{t-1}$	
$\Delta \ln E_t$	…	1.4131 [0.2622]	1.8398 [0.1798]	6.0881* [0.0070]	4.5234** [0.0211]	-0.5347*** [-1.7700]
$\Delta \ln Y_t$	1.8804 [0.1727]	…	8.8466* [0.0050]	2.0401 [0.1503]	10.6055* [0.0004]	…
$\Delta \ln Y_t^2$	1.8914 [0.1710]	9.92245* [0.0040]	…	1.6792 [0.2061]	12.6005* [0.0001]	…
$\Delta \ln C_t$	0.7703	2.1153	2.5616***	…	2.1289	-0.7981*

	[0.4735]	[0.1417]	[0.0973]		[0.31400]	[-3.8167]
$\Delta \ln PG_t$	2.6534*** [0.0894]	0.4792 [0.6246]	0.5332 [0.5930]	0.5343 [0.5923]	…	…
	$\sum \Delta \ln E_{t-1}$	$\sum \Delta \ln Y_{t-1}$	$\sum \Delta \ln Y_{t-1}^2$	$\sum \Delta \ln C_{t-1}$	$\sum \Delta \ln G_{t-1}$	
$\Delta \ln E_t$	…	0.8746 [0.4296]	1.1247 [0.3406]	9.1230* [0.0011]	1.4922 [0.2442]	-0.6271** [-2.1325]
$\Delta \ln Y_t$	1.0331 [0.3700]	…	5.9025** [0.0125]	2.0483 [0.1493]	1.1793 [0.3234]	…
$\Delta \ln Y_t^2$	0.9992 [0.3819]	6.4542* [0.0099]	…	1.7230 [0.1930]	1.2980 [0.2902]	…
$\Delta \ln C_t$	1.5008 [0.3326]	0.6535 [0.5232]	0.9734 [0.3917]	…	0.0849 [0.8899]	-0.7629* [3.5040]
$\Delta \ln G_t$	0.2048 [0.8161]	0.0335 [0.9671]	0.0096 [0.9906]	0.6615 [0.5245]	…	…
Note: *, ** and *** denote the significance at the 1, 5 and 10 per cent level, respectively.						

In short run, coal consumption Granger causes CO_2 emissions. Economic globalization Granger causes CO_2 emissions and in resulting, CO_2 emissions Granger causes economic globalization i.e. feedback effect. The unidirectional causality is found running from economic growth to economic globalization.

V. Conclusion and Policy Implications

This paper investigates the validity of the EKC hypothesis by incorporating coal consumption and globalization in CO_2 emissions function over the period of 1970-2012 for Chinese economy. The combined cointegration approach by Bayer and Hanck, (2013) is applied to examine the long run relationship between the variables and robustness of long run relationship is tested by applying the ARDL bounds testing approach in the presence of structural breaks in the series. The VECM causality framework is used for detection of direction of causal relationship amid the variables. Our results confirm the presence of long run relationship among the variables. The EKC hypothesis is validated. Coal consumption increases CO_2 emissions dominantly and globalization improves the environmental quality. CO_2 emissions are Granger caused by economic growth and globalization (economic, political and social). Coal consumption causes CO_2 emissions and in resulting, CO_2 emissions cause coal consumption in Granger sense.

Globalization increases per capita income and also causes technological enhancement in China, which contributes to decrease in environmental degradation intensity. Thus, our empirical study validates the nexus between globalization and environmental quality. At the low level of income environmental degradation tend to rise as people are willing to accept increasing environmental degradation in exchange for higher consumption. However, as a country reach higher living standards through globalization process, citizen demands better environmental quality. Within the process of globalization in China, we have evidence of improving social and ecological conditions. However, for current process of globalization to be sustainable in the long run, China needs to participate more in the process of market integration with its regional trading partners by lowering or removing the trade barriers. Environmental and social sustainability are necessary condition of the sustainability of globalization in the long run and thus economic development of a country. Therefore, Chinese government should focus on improving environmental quality. To achieve sustainable growth with an ever increasing energy demand, the Chinese government should make every effort to improve energy efficiency and reduce pollutant emissions. China's energy policies should focus on supplying more clean and low-carbon energy. China already is experiencing serious environmental problems through energy activities as coal accounts for about 70% of total primary energy in China which is the dominant source of carbon emissions in 2011-12 (China Energy Statistical Yearbook 2012). Chinese Government's energy policy should diversify energy source to reduce its' reliance on coal. China should take active measures to increase the utilization of cleaner energy sources such as wind, solar, natural gas, nuclear power and hydroelectric power.

As economic development and globalization in China continues, environmental problems in general will worsen with the projected rapid increases in energy consumption. China's energy development strategy should include an energy conservation priority policy, and at the same time developing renewable energy. Government should adopt laws, regulations, and fiscal policies to enhance efficient use of energy. Vehicle emissions problem in particular require special attention, especially those associated with increases in freight and passenger transport energy consumption. Policy makers should also emphasis on development of strategic oil reserve to sustain long term economic development. China's long term sustainable economic growth will depend on its less resource-depleted development pattern and cut its reliance on resource and energy intensive industries. Rapid industrialization in the urban areas hugely contributed to the environmental degradation in China. China should take measures to promote the development and modernization of agriculture sector, which will slow down the rapid urbanization to alleviate environment pressure.

For future research on EKC hypothesis in China, regional and provincial data can be used as the aggregate data used to weaken the correct causality and cause the spurious feedback relationship. The investigation of the EKC hypothesis in presence of globalization on different sector of the economy such as agriculture, transport, commerce, industry, and households could shed more light on the effect of globalization on the different sector of the Chinese economy. Such studies can be very interesting for energy policy design as these would be micro foundation for aggregate macro-economy.

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