



Energy Consumption in China and Underlying Factors in a Changing Landscape: Empirical Evidence since the Reform Period

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Abstract:

In recent decades, the phenomenal growth in the Chinese economy has created increasing energy demand. This research analyses energy consumption in China by following its trajectory since the economy started its reform program until recent times. We use the KOF globalisation index to explore the dynamic link between economic growth, financial development, trade and economic, social and political dimensions of globalisation and energy consumption. Time series econometric techniques are used in establishing stationarity, long-run dynamics and causality of the series. The findings suggest that globalisation decreases energy demand in the short run but increases it in the long run. However, the effect of financial development on energy demand in China is opposite to the globalisation effect on energy consumption. Granger causality reveals a feedback effect between economic globalisation and financial development; globalisation in China can only reduce energy demand if China develops its financial sector to a greater extent. In future, China should invest in its financial sector and low-carbon energy alternatives to achieve sustainable development.

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1. Introduction

Since the advent of globalisation, the Chinese economy has been, and is expected to remain, a source of great motivation for most of the developing and low income countries. During the last three decades, the economy has transformed in multiple directions. It smoothly shifted from being centrally planned to a market-based economy while sustaining rapid growth and socio-economic development [[1]]. Despite being the home of the largest population in the world and having severe socio-political issues at the beginning of economic reform in the early 1970s, the country has miraculously maintained a 10% average annual growth rate for three consecutive decades. This spectacular growth is mostly associated with the trade liberalisation, a favourable investment environment both for domestic and international investors, and promoting the private sector along with the public sector. The thoughtful economic restructuring succeeded to attract remarkable foreign direct investment (FDI) and made China the financial hub in East Asia. [[2]] has reviewed the literature on financial development-economic growth on China.

Economic development in China has had serious ramifications for the use of natural resources and energy. Energy consumption has ballooned; the effects on social and economic welfare to the Chinese people are substantial.⁵ Mass migration to the urban cities and forced resettlements, public health problems and social unrest are associated with industrialisation, urbanisation and environmental degradation. The social costs of environmental degradation are reflected through an increase in health expenditure and productivity losses due to urban air pollution. Policy advisers in China have become increasingly cognisant of improving the environment. Opening the door to non-governmental organisations and the media, the international community, and multinationals have been powerful instruments in shaping environmental practices.

⁵ Energy consumption and energy demand is used synonymously in this paper.

The empirical evidence on the effects of globalisation, considering different aspects on energy demand and environmental degradation, is non-existent in the case of China. Chinese economic development has created economic, social and political problems. Contrary to trade openness; globalisation is a multidimensional phenomenon as discussed in [[3], [4]]. In this paper, we use the Konjunkturforschungsstelle (KOF) index of globalisation, a composite indicator developed by the Swiss Economic Institute that covers the effect of globalisation in three broad dimensions (i.e., economic, social and political). To our knowledge, this is the first study examining the effects on energy demand that consider various dimensions of globalisation in China with other control variables.

Meanwhile, research has been very much focused on the environmental consequences of growth and has sufficiently ignored the exogenous role of energy consumption in terms of globalisation and market integration [[5], [6]]. Energy security has become the integral part of foreign policy (Kalicki and Goldwyn, 2005) and a growing global challenge of the century for China [[6]]. Energy management and related technological improvements help economies to gain some competitive advantage [[7], [8]]. More importantly, the recent literature suggests financial development as one of the key endogenous factors, while assessing the impact of trade openness on economic growth as in [[9], [10], [11]]. In subsequent periods, this leads to efficient energy management and energy investment practices. We posit financial development, economic growth, trade openness and economic, social and political aspects of globalisation in influencing energy consumption.

China is highly dependent on the energy resources and this is expected to rise over time (EIA, 2013).⁶ There is a growing body of literature investigating the energy-growth nexus. Interestingly, keeping in view future trends in energy demands and policy needs, the literature on energy policy research has shifted from technologically advanced economies to

⁶ <http://www.eia.gov/countries/cab.cfm?fips=CH>

the developing and emerging world. Energy demand in China is expected to grow enormously as growing competition with states and highly supported policies to increase foreign investment will further mobilise the industrial sector. Growing incomes are increasing the use of transportation, electricity consumption and overall household energy demand. The intensive urbanisation process results in energy demand and more metropolitan cities emerging as population and the industrial sector simultaneously grow and rural populations are squeezed. Being in a transition phase and grappling with growth in energy demand, China is moving towards both conventional and renewable energy resources to meet the industrial and household energy needs as emphasised in [[12]]. The overall change in energy resource trend has significant environmental implications for China.

The literature is ambiguous on whether globalisation has increased the demand for conventional energy to fulfill the growing energy demand or if there is a gradual switching towards renewable and clean energy sources through the attainment of technical efficiency in the Chinese energy sector. These effects are portraying whether the economy endures the positives or negatives of globalisation in terms of energy consumption. This trend, in both cases, contributes to growth, but the growth impact in a previous study is sustainable in the long term with a reduced scale effect on the energy sector.

To our knowledge, this paper addresses for the first time the direct effects of economic, social and political globalisation on energy consumption in China. The paper considers financial development, economic growth, trade openness as the three dimensions of globalisation and their possible effects on overall energy consumption..

Figure 1 portrays the time series trends of variables considered in our model. This depicts an irregular trend in linking globalisation and energy demand with other control variables. Therefore, we posit there is a need for a detailed study on China that analyses the effects of globalisation and trade openness on energy use.

Figure-1 (paste here)

The remainder of the paper is set out as follows. Section 2 presents a brief literature review highlighting three key factors we consider in explaining energy consumption. We focus here on the studies from the developing and emerging countries. Section 3 describes the model with empirical steps we follow for estimation purposes. Section 4 analyses the findings with discussion. In the concluding section, we add the policy implications of our findings with a few recommendations.

2. A Brief Overview of the Literature

In reviewing the literature, we highlight economic growth, financial development, trade openness and globalisation as the sources of energy consumption.

2.1. Economic Growth and Energy Demand

Theoretical and empirical literature on energy consumption and economic growth is well-documented - see, for example, [[13], [14]]. GDP causes energy consumption, as described in studies [[15], [16], [17]]. In other studies, however, causality is established to run from energy consumption to GDP [[18], [19], [20]]. A bi-directional causality has been established in the studies (e.g., [[21], [22], [23]]) or non-causality is established in [[24], [25], [26]]. [[27]] emphasises the role of technology in explaining the energy-growth nexus where coal is considered as a primary source of energy in the case of China.

2.2 Financial Development and Energy Demand

Linking financial development with energy consumption has been a wide area of research, particularly for developing and emerging countries where the financial and energy sectors have expanded in the last three decades. With financial development, these countries have significantly been engaged in industrialisation, trade and building new infrastructure in recent years. These have significant effects on energy use. In the case of Tunisia, [[28]] reports a uni-directional relationship running from energy consumption to financial development, while [[29]] establishes a long-run bi-directional causality between energy consumption and

financial development. For twenty-two emerging countries, [[30]] establishes the positive effect of financial development on economic growth. Using different financial indicators from the banking sector and stock market, [[31]] finds financial development has a significant positive effect on energy consumption with indicators from banks, while only the stock market turnover has a positive relationship established. The competition from foreign banks encourages flexibility in the system and opens new opportunities for investors. This has a positive effect on economic growth. In the case of Malaysia, [[32]] establishes that both economic growth and finance have a significant effect on energy use. [[33]] establishes a significant impact of financial development on energy consumption only for old EU members in their sample.

At the Chinese province level, a panel study by [[34]] establishes that financial development has a significant positive effect on energy consumption. The findings are sensitive to the measure of financial development. [[35]] finds that financial development has a positive effect in reducing environmental pollution. In the case of Turkey, [[36]] finds a long-run relationship between per capita energy consumption and financial development. A causal relationship running from per capita energy consumption to financial development is established in the short run. In the long run, financial development causes changes in per capita energy consumption. [[37]] confirms this in the case of the Sub Saharan Africa, where energy consumption plays a significant role in improving the financial sector.

2.2. Trade, Globalisation and Energy Consumption

Globalisation enhances economic and trading activities through an increase in foreign direct investment, and the transfer of advanced technology from developed countries to developing nations. The literary debate on the relationship between globalisation and energy consumption trade openness was initiated with the advent of industrialisation [[38]]. The last three decades have witnessed the most proliferating periods of trade openness [[39], [40]]. The

world economy has grown at its fastest rate in human history. The fruits of globalisation are disseminated far and wide and many of the developing economies have been transformed into the development phase, and many are in the process [[41], [42]]. However, industrialisation and globalisation have direct consequences on the environment.

Initially, trade openness was considered as the sole indicator of globalisation and was tested for its contribution towards economic growth. A seminal study of [[43]] examines the environmental consequences of the Northern America Free Trade Agreement (NAFTA). Their findings establish the dominance of the scale effect of trade openness on environmental degradation keeping the composition effect and technique effect constant. However, energy consumption is for the first time incorporated as the chief source of environmental degradation along with growth and trade by [[44]] and a positive relationship was found among all cointegrating vectors. The studies using a panel of countries are conducted by [[45], [46], [47]], and [[48]]. The single country study includes [[46]] for USA, [[49]] for Turkey, and [[50]] for Mongolia. The findings from both panel and single country analyses have been mixed and vary due to the stages of economic development, time period and econometric techniques being used.

Following [[51]], globalisation reduces environmental degradation through investment in energy-efficient technologies for production. Globalisation may transfer pollution intensive industries to countries where environmental regulations are weak as suggested in [[52]]. [[53]] and [[54]] identify the technique effect of globalisation as a source of improving environmental quality. In the case of China, [[55]] establishes that trade openness deteriorates environmental quality as China exports to the world.

The economies with technological change (technique effect) receive a positive impact on the environmental quality as a technology improvement contributes to cleaner production [[56]]. After attending the threshold income level, these economies attract foreign capital into

the production process. The capital movement enhances technology and the overall competitiveness of industries. The process continues with economic development and improves environmental degradation.

3. Model, Data and Empirical Steps

3.1 Model and Data

A shortage of natural resources, environmental degradation and lack of coordination between economic and social development are identified as the major obstacles in modern China. Economic reforms have been associated with social and political challenges [[57]] and others. The energy consumption growth in China has wide implications for air pollution, greenhouse gas (GHG) emissions and energy shortages, both in China and the world.

We posit that sources of increasing energy demand are due to financial development, increase in trade, and economic, social and political dimensions of globalisation as China integrates with rest of the world. The main objective of this research is to estimate energy demand in this changing landscape since the reform period. After the mid-1990s, economic reforms, along with constant actions by the Chinese government, have improved energy consumption efficiency. This empirical setting is uniquely designed to capture the impact of globalisation in the context of economic, social and political liberalisation on the energy demand function along with other control variables discussed above. Our empirical model is as follows:

$$EC_t = f(Y_t, FD_t, TO_t, EG_t, SG_t, PG_t, G_t)$$

Eq. 1

Eq. 1 represents the functional form of the model; where, EC_t is the primary energy demand and $Y_t, FD_t, TO_t, EG_t, SG_t, PG_t, G_t$ denotes economic growth, financial development, trade openness, economic globalisation, social globalisation, political globalisation and overall globalisation, respectively. Furthermore, we parameterised Eq.1 as follows:

$$\ln EC_t = \alpha_1 + \underbrace{\alpha_2 \ln Y_t}_{\text{Income Effect}} + \underbrace{\alpha_3 \ln FD_t}_{\text{Finance Effect}} + \underbrace{\alpha_4 \ln TO_t}_{\text{Trade Effect}} + \underbrace{\alpha_5 \ln EG_t}_{\text{Economic-Glob. Effect}} + \underbrace{\alpha_6 \ln SG_t}_{\text{Social-Glob. Effect}} + \underbrace{\alpha_7 \ln PG_t}_{\text{Political-Glob. Effect}} + \underbrace{\alpha_8 \ln G_t}_{\text{Overall-Glob. Effect}} + \mu_t$$

Eq. 2

The coefficients in Eq. 2 can be interpreted as the elasticity value of each variable with respect to energy consumption. Energy consumption is measured by the total energy use (kt of oil equivalent). Net domestic credit is taken as the proxy of financial development. To measure trade openness, we use a popular measure, the value of exports plus imports in current US\$ to GDP. [[58]] explains the significance of social awareness to accept renewable energy innovation. [[59]] analyses the 1974 energy crisis using survey data from Los Angeles residents and concludes that political system support has a significant impact on the public response to energy consumption. [[60]] states the importance of a political system in ensuring the country's energy security. In the case of China, the socio-economic and political effects of globalisation may have a significant effect on energy demand as discussed in academic research [[61]]. Therefore, in order to capture the globalisation effects of China, we use the Swiss Economic Institute's KOF index. This index combines three aspects of globalisation, viz., *economic globalisation*, which accounts for economic flows with an allowance for restrictions to trade and capital; *social globalisation*, which accounts for the spread of ideas, information, images and people; and *political globalisation*, which accounts for the diffusion of government policies (KOF Index-2013).⁷ These three components are assigned with weights of 37%, 36% and 26%, respectively, and the combined index is measured on a range between 1 and 100, with a higher score reflecting a greater degree of globalisation. For China, the overall globalisation index along with its sub-indices has significantly improved between 1971 and 2013. For example; during the same period, the economic, social and political indices have increased from 25.22, 7.89, 27.72 to 51.12, 48.94, and 85.85,

⁷ China ranks 120, 90, 43 and 75 respectively for economic, social, political and overall aspects of globalisation out of 207 countries in 2015 KOF index.

respectively. However, the overall globalisation index rose from 19.22 in 1971 to 59.43 in 2013. The data suggests that China has progressed in all three dimensions of globalisation. The country has achieved tremendous progress and shifted from central economic planning to market reforms. This does have an impact on its present and future energy demand. Being the largest energy consumer in the world, China potentially possesses influence over regional and global economic and geo-political issues. Its future energy policies will reshape the global energy flows.

We utilise annual time series data from 1971 to 2013. The data for energy consumption, economic growth, financial development and trade openness are extracted from the World Development Indicators (WDI) series published by the World Bank [[1]]. However, the data for the four components of globalisation are taken from the KOF-Globalisation index (2013), the index developed by the Swiss Federal Institute of Technology, ETH-Zurich.

3.2 Empirical Steps

3.2.1 Unit Root Tests

The time series data analysis necessitates that all the series should be stationary. Therefore, we apply the traditional unit root tests through augmented Dickey–Fuller (ADF) and Philips–Perron (PP) developed by [[62]] and [[63]] respectively.

However, [[63]] argued that the traditional ADF and PP unit root test results could be biased in the case of the null hypothesis H_0 being not rejected because of the existence of one-time permanent change in the data. The key reason behind this argument is that the presence of any structural break is always assumed to be fixed in priori following the asymptotic distribution theory. In the literature, Zivot and Andrews [[64], [65], [66], [67], [68] and [69]] and others, propose different approaches to accommodate the structural break endogenously into the model instead of an exogenous element. The ZA test captures one

structural break in the series. For a robustness check, we conduct the ZA unit root test to check the stationarity of data while accommodating the single structure break in the series.

3.2.2 Cointegration Test

After confirming the time series are stationary using the ZA test with a single structure break test, we conduct a cointegration test to establish the long-run dynamics of our model. For this purpose, we choose the autoregressive distributed lag (ARDL) bounds testing approach developed by [[70]] and [[71]]. The ARDL bounds test approach has an ability to examine the long-run association between the variables; even if the series has a mixed order of integration, i.e., I(0) and I(1) and is small in sample size. The time-series econometric literature on bounds testing procedure is developed, and currently is the most preferred approach to cointegration in applied economics. However, the ZA unit root test ascertains the order of integration and checks the stationarity of each series to confirm that none of the series has I(2) order of integration and to turn the model in a more robust form. The cointegration test analyses the impact of financial development, trade openness economic growth, and three dimensions of globalisation on energy demand in China. The bounds test constitutes two separate critical values that are allied to all regressors in the model at purely I(1), I(0), or fractionally I(1)/I(0). The hypothesis of no cointegration is rejected on the basis of the calculated F-statistic. The ARDL model is represented by eq. 3;⁸

$$\begin{aligned}
\Delta \ln EC_t = & \vartheta_1 + \vartheta_{EC} \ln EC_{t-1} + \vartheta_Y \ln Y_{t-1} + \vartheta_{FD} \ln FD_{t-1} + \vartheta_{TO} \ln TO_{t-1} + \vartheta_{EG} \ln EG_{t-1} + \\
& \vartheta_{SG} \ln SG_{t-1} + \vartheta_{PG} \ln PG_{t-1} + \vartheta_G \ln G_{t-1} + \sum_{i=1}^p \vartheta_i \Delta \ln EC_{t-i} + \sum_{j=0}^r \vartheta_j \Delta \ln Y_{t-j} + \\
& \sum_{k=0}^r \vartheta_k \Delta \ln FD_{t-k} + \sum_{l=0}^r \vartheta_l \Delta \ln TO_{t-l} + \sum_{m=0}^r \vartheta_m \Delta \ln EG_{t-m} + \sum_{m=0}^r \vartheta_m \Delta \ln SG_{t-m} + \\
& \sum_{m=0}^r \vartheta_m \Delta \ln PG_{t-m} + \sum_{m=0}^r \vartheta_m \Delta \ln G_{t-m} + \mu_t
\end{aligned} \tag{Eq. 3}$$

⁸ Similarly, the number equations will be equal to the number of variables in the model, but we consider only one equation to conserve space.

Eq. 3 above contains 1st difference operator denoted by Δ and μ_t represents stochastic terms. The suitable lag length is selected using Akaike Information Criteria (AIC). Whether the underlying vectors are cointegrated or not, the decision is made on the basis of calculated F-statistics and selected lag length. The null hypothesis is: $H_0 : \alpha_{EC} = \alpha_Y = \alpha_{FD} = \alpha_{TO} = \alpha_{EG} = \alpha_{SG} = \alpha_{PG} = \alpha_G = 0$ against the alternate hypothesis: $H_a : \alpha_{EC} \neq \alpha_Y \neq \alpha_{FD} \neq \alpha_{TO} \neq \alpha_{EG} \neq \alpha_{SG} \neq \alpha_{PG} \neq \alpha_G \neq 0$. [[71]] explains the relationship of cointegration between variables based on two asymptotic critical value bounds, the upper critical bounds (UCB) and lower critical bounds (LCB), interrogated at I(0) and I(1) order, respectively. If the calculated F-statistic [$F_{EC}(EC/Y, FD, TO, EG)$, $F_{EC}(EC/Y, FD, TO, SG)$, $F_{EC}(EC/Y, FD, TO, PG)$, and $F_{EC}(EC/Y, FD, TO, G)$ lies between upper and lower critical bounds, it means the cointegration results are inconclusive; however, if the values of the F-statistic fall above the upper bound limits, the null hypothesis is rejected, and the values below the lower bound limits conclude there is no cointegration. Moreover, the long-run and the short-run relationship between the variables is also assessed using an error correction model (ECM). ECM tests the relationship of all variables both in short-run and long-run phenomenon and its results further help us to determine both the long-run and short-run impact of explanatory variables on energy demand.

$$\ln EC_t = \mathcal{G}_1 + \sum_{k=1}^r \mathcal{G}_{1k} \Delta \ln EC_{t-k} + \sum_{k=1}^r \mathcal{G}_{2k} \Delta \ln Y_{t-k} + \sum_{k=1}^r \mathcal{G}_{3k} \Delta \ln FD_{t-k} + \sum_{k=1}^r \mathcal{G}_{4k} \Delta \ln TO + \sum_{k=1}^r \mathcal{G}_{5k} \Delta \ln EG_{t-k} + \sum_{k=1}^r \mathcal{G}_{6k} \Delta \ln SG_{t-k} + \sum_{k=1}^r \mathcal{G}_{7k} \Delta \ln PG_{t-k} + \sum_{k=1}^r \mathcal{G}_{8k} \Delta \ln G_{t-k} + \theta ECT_{t-1} + \mu_t \quad \text{Eq. 4}$$

3.2.3 Granger Causality Test

In recent applied time series econometric literature, the use of causal mechanisms has been a common practice [[72]] and the Granger causality test developed in [[73]] is the most

frequently cited reference. Therefore in the next step, to transform our model, the data are simulated for augmented Granger causality using [[74]] test procedure. The main motivation to prefer the Toda-Yamato approach over other commonly used Granger causality test procedures (i.e. VECM Granger causality approach) is that it determines the causal links among the underlying vectors, even if the series are either integrated in a different order or non-integrated. Hence, based on asymptotic theory, the Toda-Yamamoto test provides an appropriate approach to test the causal links between energy consumption and globalisation. The lag augmented VAR model of the Toda-Yamamoto model is expressed in the following model:

$$Y_t = \alpha + \sum_{j=1}^{c+d} \delta_j Y_{t-j} + \sum_{k=1}^{e+d} \phi_k Y_{t-k} + \varepsilon_{yt}$$

Eq. 5

$$X_t = \alpha + \sum_{j=1}^{c+d} \phi_j X_{t-j} + \sum_{k=1}^{e+d} \psi_k X_{t-k} + \varepsilon_{xt}$$

Eq. 6

In the above equation, Y_t and X_t are the two vectors, d represents the maximum order of integration for all underlying vectors in the model, c and e are the optimal lags structure for the dynamic model, and ε is the error term calculating the white noise across the model. During the simulation process, Wald test statistics are used to test the linear restrictions in the VAR model and we ignore the non-stationary data identified under the chi-squared distribution under the null hypothesis. However, the [[74]] process ensures the asymptotic distribution theory. The null and alternate hypothesis for Eq. 5 and Eq. 6 are tested as below:

For null hypothesis; $H_0 = \sum_{k=1}^e \phi_k = 0$ or X_t does not Granger cause Y_t

For alternate hypothesis; $H_1 = \sum_{k=1}^e \phi_k \neq 0$ or X_t Granger cause Y_t

For null hypothesis; $H_0 = \sum_{k=1}^e \psi_k = 0$ or Y_t does not Granger cause X_t

For alternate hypothesis; $H_1 = \sum_{k=1}^e \psi_k \neq 0$ or Y_t Granger cause X_t

4. Empirical Findings and Discussion

Table 1 exhibits the core characteristics of collected data. The figures related to skewness and kurtosis show the normality of the collected data for analysis. The lower standard deviation suggests the degree of consistency in our data series over time.

Table 1 (paste here)

Table 2 shows the results of the ZA-unit root test results, identifying the single break point in the series. The results conclude that the series; $\ln EC_t$, $\ln Y_t$, $\ln FD_t$, $\ln TO_t$, $\ln EG_t$, $\ln SG_t$, $\ln PG_t$ and $\ln G_t$ are stationary at first difference with time breaks 2002, 1982, 1996, 2007, 1983, 2001, 1991 and 1991, respectively. All of these break dates are significant for China. For example, China initiated clean technology in early 2000; other dates coincide with the beginning of various reform programs along with China's joining date with the World Trade Organization (WTO). The identified time breaks imply that the economy has observed significant policy shocks at a particular point of time, resulting in the permanent shift in the series. The values of the t-statistic are significant at the 1% level of significance except $\ln FD_t$, which is significant at the 5% significance level. However, the values in small parenthesis against each t-statistic show the lag order based on AIC. As discussed in previous sections, the ZA-unit root test gives unbiased results and confirms that the stationary time series are ready for cointegration analysis.

Table 2 (paste here)

Table 3 presents the findings of the ARDL bounds test. The lag length selection is an important component of the ARDL bounds test because the inappropriate lag length selection may lead to misleading results [[75]]. Therefore, the model incorporates the AIC criteria for the selection of appropriate lag order for each variable, and the results of optimal lag length are reported in column 2 of Table 3. However, the critical bounds are taken from [[76]], for the decision of cointegration relationship between the variables. Considering EC_t as an independent variable, we check four different models [i.e. $F_{EC}(EC/Y,FD,TO,EG)$, $F_{EC}(EC/Y,FD,TO,SG)$, $F_{EC}(EC/Y,FD,TO,PG)$ and $F_{EC}(EC/Y,FD,TO,G)$] in identifying the long-run association between the different components of globalisation in the presence of economic growth, financial development, trade openness, on the energy consumption. The calculated F-statistics, are greater than the upper bound limits at the 1% level of significance. This suggests the cointegration among the vectors of each model following the ARDL test and confirms the long-run association between the variables. Further, it can be explained that the series of energy consumption, economic growth, financial development, trade openness and globalisation (Economic-Social-Political-Overall) are individually cointegrated in the case of China for our period of study. In the next step, we conduct the short- and long-run analysis.

Table 3: (paste here)

Table 4 reports the long-run and short-run findings for our model. The results are significant and we conclude that in the short run, the overall impact of globalisation ($\ln G_t$) is negative, however, this effect turns positive in the long run. A 1% increase in globalisation decreases energy demand by 0.6% and increases energy demand by 0.8% in the short run and long run respectively. Besides, taking the different components of globalisation into account separately, the impact of economic, social and political globalisation has similar patterns. A 1% increase in all three components decreases energy demand by 0.28%, 0.22%, and 0.30% in the short run, and increases energy demand by 1.24%, 0.38% and 0.94% in the long run

respectively. This notion further implies that the globalisation in China reduces energy demand in the short run, but in the long run it increases energy demand. Economic globalisation has the highest implications for the energy demand function in the long run. However, the impact of political globalisation and social globalisation comes second and third, respectively.

Economic growth and trade openness have a positive and significant impact on the energy demand, both in the short run and long run. In the short run, a 1% percent increase in economic growth and trade openness, increases energy demand by 0.21% and 0.33%, respectively. However, in the long run, a 1% increase in economic growth and trade openness enhances energy demand by 1.9% and 0.25%, respectively. In summary, there is a growing positive influence of economic growth on energy demand, from the short run to the long run, but trade openness shows a decreasing effect during the same channel. It signifies that in comparison to its short-run effect, trade openness reduces energy demand in the long run for China. Our analysis observed that there is quite dissimilarity in the results of economic globalisation and trade openness. It means the previous studies which considered only trade openness as the proxy of globalisation may have produced biased findings.

Financial development has a positive and significant effect in the short run, and a negative and significant impact in long run for energy demand. A 1% increase in financial development increases energy demand by 0.28% and decreases energy demand by 0.02%, in the short run and long run respectively. Moreover, the coefficient of the error-correction-model reports that the deviation in the short run is corrected for long-run equilibrium by 19 to 26 percent on a year-on-year (YOY) basis.

A short-run diagnostic test is also conducted and the findings are reported in the lower part of Table 4. The results confirm that the model is normally distributed and does not possess serial correlation, heteroskedasticity, and ARCH problems. The results of the Ramsey

reset test further confirm that the functional form of the model is well specified. The overall results of the diagnostic test authenticate the long-run and short-run analysis, the model is robust, and findings are appropriate for policy use.

Table 4: (paste here)

Following [[77]], we test for stability for each model using a cumulative sum (CUSUM) of recursive residual and cumulative sum of squares (CUSUMSQ) of recursive residuals. The results are shown from Figures 2-9. The straight line within critical bounds confirms that the model is stable and specified parameters are well specified and consistent throughout the examination at the 5% level of statistical significance.

Figures 2-9 (paste here)

The existence of cointegration between series anticipates the causal links among the series. We use the Toda-Yamamoto (modified Wald test) Granger causality approach to determine the causal links between the variables. Table 5 displays the findings from the Granger causality test. The results confirm the feedback effect between energy demand and economic growth. The uni-directional causality is running from economic growth to globalisation. Energy demand Granger causes economic, social, and political globalisation. Financial development Granger causes energy demand and there is a feedback effect between energy demand and economic globalisation. However, trade openness Granger causes financial development and overall globalisation. There is feedback effect between energy demand and trade openness. This notion can further be enumerated in a way that economic globalisation affects energy demand through financial development.

Table 5: (paste here)

5. Conclusion and Policy Recommendations

This research empirically investigates the link between three dimensions of globalisation, financial development, economic growth and trade openness and energy consumption

considering a significant four decades of time where China has been in transition to become a world super power. We employ the dynamic ARDL bounds test approach to cointegration and the Toda-Yamamoto (modified Wald test) procedure for Granger causality analyses. After confirming all the series are stationary with a single structural break, the ARDL bounds test results confirm the existence of cointegration between underlying variables. Subsequently, the long-run and short-run analysis is also conducted using an error correction model (ECM). The findings suggest that globalisation decreases energy demand in the short run but increases it in long run. However, the effect of financial development on energy demand in China is opposite to the globalisation effect. As Granger causality reveals a feedback effect between economic globalisation and financial development, globalisation in China can only reduce energy demand if China develops its financial sector to a greater extent.

This study adopts a unique way to explore the energy-globalisation nexus using the KOF globalisation index which includes three dimensions, viz., economic, social and political of globalisation. This is significant for China as increasing energy demand and economic growth have severe consequences on economic, social and political aspects.

From policy perspectives, the empirical findings suggest that globalisation helps the Chinese economy to achieve further economic growth. Therefore, it should continue its open-door policy to further strengthen its economic, social, and political institutions. However, on the other hand, there is a need for sufficient financial deepening to ensure efficient allocation of investment. This will help human development, the improvement of labour productivity, the prioritisation of energy conservation projects, the promotion of renewable and alternative low-carbon energy sources, and the creation of a competitive edge in technology, both in the conventional energy and alternate energy sectors. In the light of Granger causality, financial development is instrumental for the accomplishment of the sustainable development goal.

Prevention of energy shortfalls would assist in bridging the gap both from social and political aspects to ensure China benefits from the effects of globalisation.

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Figure-1: Trend in Variables

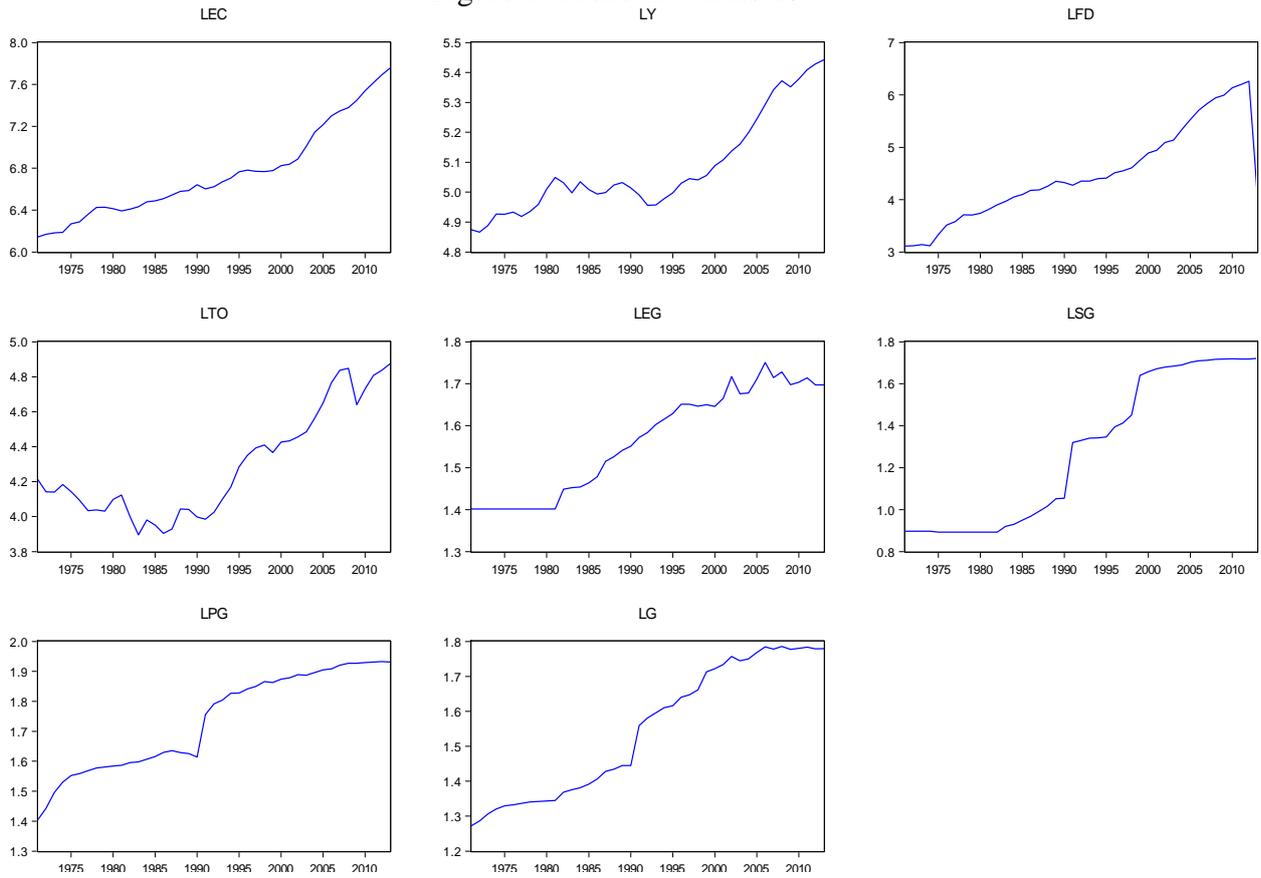


Figure-2: Plot of Cumulative Sum of Recursive Residuals

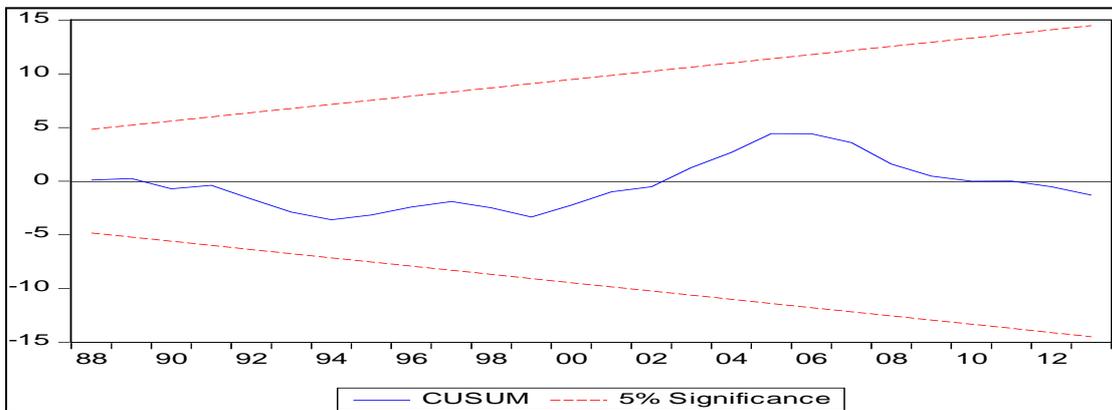


Figure-3: Plot of Cumulative Sum of Square of Recursive Residuals

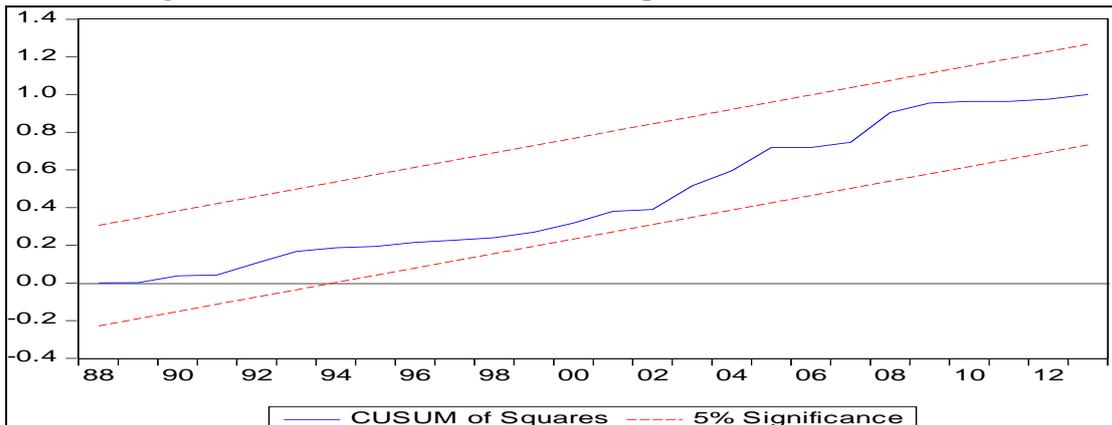


Figure-4: Plot of Cumulative Sum of Square of Recursive Residuals

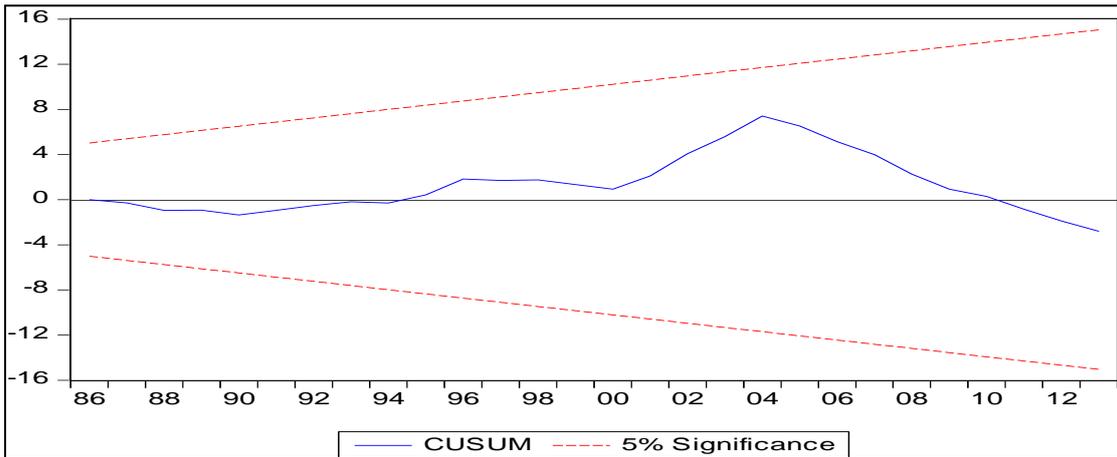


Figure-5: Plot of Cumulative Sum of Square Recursive Residuals

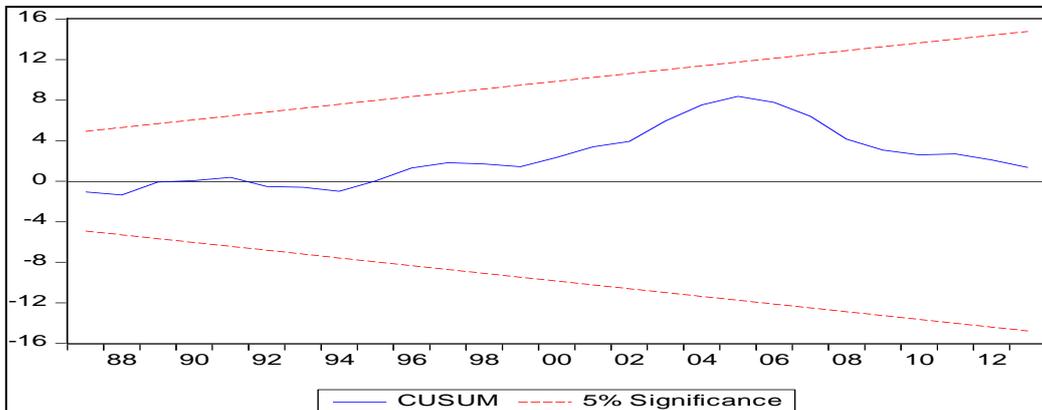


Figure-6: Plot of Cumulative Sum of Recursive Residuals

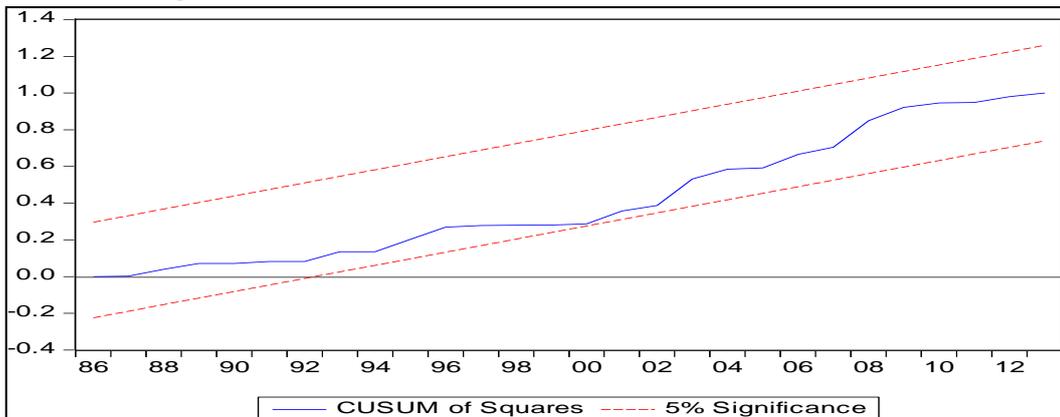


Figure-7: Plot of Cumulative Sum of Square of Recursive Residuals

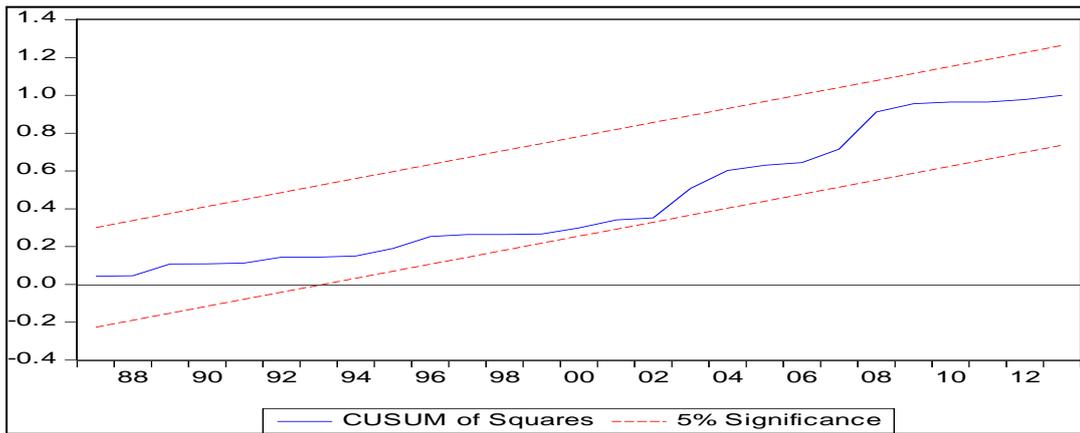


Figure-8: Plot of Cumulative Sum of Recursive Residuals

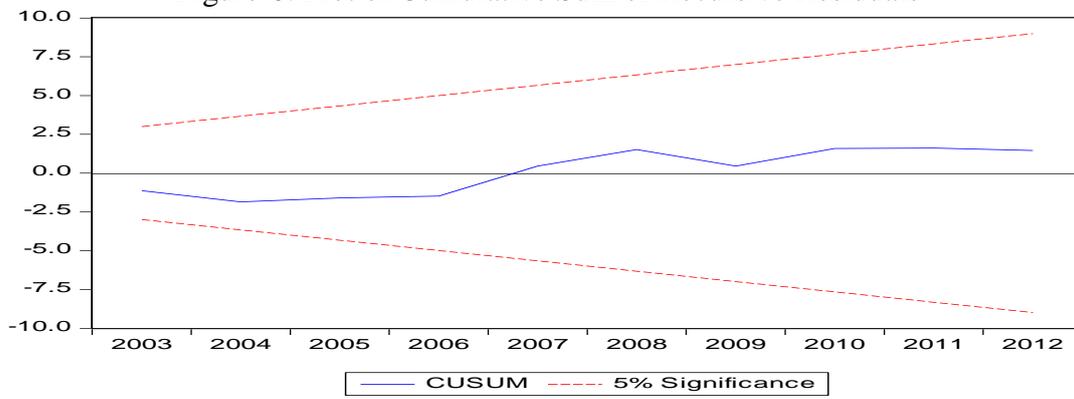


Figure-9: Plot of Cumulative Sum of Squares of Recursive Residuals

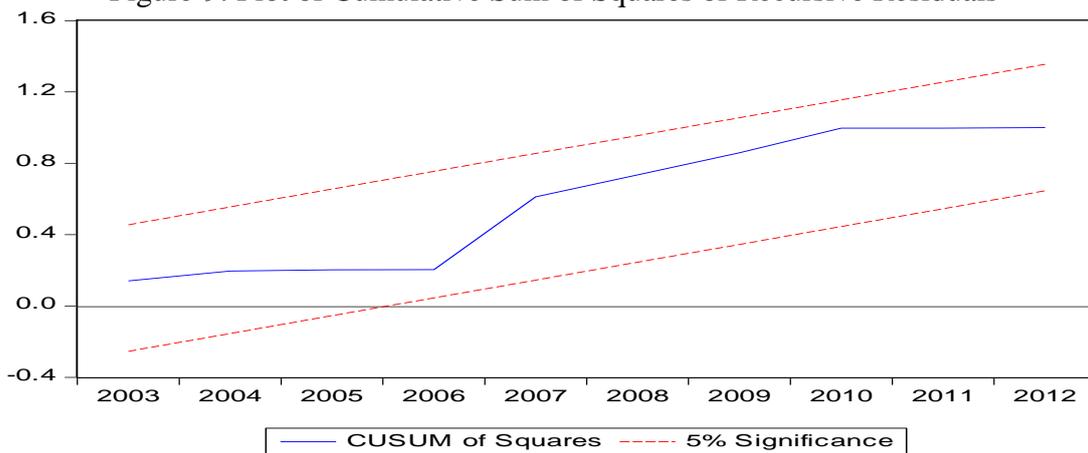


Table 1: Descriptive Statistics

	$\ln EC_{it}$	$\ln Y_{it}$	$\ln FD_{it}$	$\ln TO_{it}$	$\ln EG_{it}$	$\ln SG_{it}$	$\ln PG_{it}$	$\ln G_{it}$
Mean	4.289	6.753	1.564	4.475	1.548	1.735	1.279	5.080
Median	4.168	6.642	1.584	4.351	1.581	1.792	1.330	5.029
Maximum	4.876	7.760	1.751	6.263	1.786	1.932	1.721	5.442
Minimum	3.896	6.143	1.402	3.114	1.272	1.404	0.892	4.867
Std. Dev.	0.306	0.443	0.125	0.898	0.188	0.164	0.352	0.165
Skewness	0.610	0.752	-0.137	0.457	-0.005	-0.229	0.117	0.963
Kurtosis	2.045	2.581	1.432	2.343	1.336	1.577	1.277	2.704
Jarque-Bera	4.296	4.372	4.541	2.268	4.960	4.006	5.416	6.800
Probability	0.117	0.112	0.103	0.322	0.084	0.135	0.067	0.033
Sum	184.423	290.391	67.252	192.427	66.581	74.594	55.008	218.430
Sum Sq. Dev.	3.943	8.257	0.656	33.855	1.484	1.125	5.197	1.137

Table 2: ZA Unit Root Test with Structural Break

Variable	Level			First Difference		
	t-statistic	Time Break	Decision	t-statistic	Time Break	Decision
$\ln EC_t$	-2.655 (1)	2003	Unit Root	-5.624* (0)	2002	Stationary
$\ln Y_t$	-2.820 (1)	2004	Unit Root	-5.439* (0)	1982	Stationary
$\ln FD_t$	-2.032 (0)	2002	Unit Root	-5.341 ** (0)	1996	Stationary
$\ln TO_t$	-3.594 (2)	1982	Unit Root	-5.834* (1)	2007	Stationary
$\ln EG_t$	-3.111 (0)	2007	Unit Root	-8.358* (0)	1982	Stationary
$\ln SG_t$	-4.663 (0)	1991	Unit Root	-7.215* (0)	2001	Stationary
$\ln PG_t$	-11.401* (0)	1991	Stationary	-7.469* (0)	1991	Stationary
$\ln G_t$	-5.778* (0)	1991	Stationary	-7.500* (0)	1991	Stationary

Note: * and ** represent significant at 1% & 5% level of significance. Lag order is shown in parenthesis based on AIC.

Table 3: The Results of ARDL Cointegration Test

Bounds Testing Approach to Cointegration				Diagnostic tests			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimated Models	Optimal lag length	Structural Break	F-statistics	χ^2_{NORMAL}	χ^2_{ARCH}	χ^2_{RESET}	χ^2_{SERIAL}
$F_{EC}(EC/Y, FD, TO, EG)$	2,0,1,0	1982	9.673*	0.209 [0.655]	0.234 [.629]	0.538 [0.764]	1.267 [0.260]
$F_{EC}(EC/Y, FD, TO, SG)$	2,0,1,2	2001	7.880*	1.833 [0.176]	0.080 [0.776]	1.856 [0.395]	1.836 [0.175]
$F_{EC}(EC/Y, FD, TO, PG)$	2,2,0,2	1991	9.067*	1.598 [0.206]	2.591 [.107]	1.053 [.590]	1.231 [.267]
$F_{EC}(EC/Y, FD, TO, G)$	2,2,2,1	1991	8.326*	1.2324 [0.267]	1.2585 [0.273]	2.251 [0.324]	2.126 [0.145]
Significance level	Critical values (T= 42) [#]						
	Lower bounds I(0)			Upper bounds I(1)			
1%	6.053			7.458			
5%	4.456			5.568			
10%	3.744			4.782			

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).

Table 4: Long and Short Run Results

Dependent variable = $\ln EC_t$								
Long Run Analysis								
Variables	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Constant	-5.168*	-4.753	-3.357**	-2.232	-4.698*	-4.445	-4.093*	-3.478
$\ln Y_t$	1.986*	7.833	1.883*	5.533	1.947*	7.896	1.888*	6.785
$\ln FD_t$	-0.027	-0.705	0.011	0.201	-0.018	-0.462	-0.019	-0.465
$\ln TO_t$	0.252**	2.048	-	-	-	-	-	-
$\ln EG_t$	1.249*	4.328	-	-	-	-	-	-
$\ln SG_t$	-	-	0.384*	3.159	-	-	-	-
$\ln PG_t$	-	-	-	-	0.945	4.850	-	-
$\ln G_t$	-	-	-	-	-	-	0.862*	3.963
R^2	0.972		0.967		0.973		0.972	
Dependent variable = $\ln EC_t$								
Short Run Analysis								
Variables	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Constant	0.015**	2.082	0.019**	2.543	0.019**	2.604	0.023**	2.613
$\Delta \ln Y_t$	0.214	0.874	0.130	0.644	0.215	1.176	0.129	0.640
$\Delta \ln FD_t$	0.287*	3.540	0.275*	3.623	0.269*	4.416	0.273*	3.366
$\Delta \ln TO_t$	0.335*	2.625	-	-	-	-	-	-
$\Delta \ln EG_t$	-0.288	-0.987	-	-	-	-	-	-
$\Delta \ln SG_t$	-	-	-0.224*	-4.144	-	-	-	-
$\Delta \ln PG_t$	-	-	-	-	-0.306*	-2.909	-	-
$\Delta \ln G_t$	-	-	-	-	-	-	0.610640*	2.740285
ECM_{t-1}	-0.199*	4.181	-0.165*	-3.092	-0.266*	-7.676	-0.196*	-3.901
R^2	0.391		0.418		0.489		0.476	
F-statistic	5.786		6.478310		8.630		1.254	
D.W	1.411		1.311		1.330			
Short Run Diagnostic Tests								
Test	F-statistic	Prob. value	F-statistic	Prob. Value				
χ^2_{SERIAL}	0.531	0.471	0.376	0.543				
χ^2_{ARCH}	0.018	0.892	0.621	0.436				
χ^2_{WHITE}	0.801	0.376	0.012	0.912				
χ^2_{REMSAY}	0.654	0.721	1.105	0.575				

Note: * and **, *** show significant at 1% and 5% and 10% levels of significance respectively.

Table-5: Toda-Yamamoto Causality Test results

Dependent Variable	Null hypothesis (H ₀) = No causality							
	$\Delta \ln EC_t$	$\Delta \ln Y_t$	$\Delta \ln FD_t$	$\Delta \ln TO_t$	$\Delta \ln EG_t$	$\Delta \ln SG_t$	$\Delta \ln PG_t$	$\Delta \ln G_t$
$\Delta \ln EC_t$	-	7.201* *	0.028	6.033* *	5.973**	6.935* *	6.618**	----
$\Delta \ln Y_t$	6.179**	-	0.003	0.451	0.704	1.435	1.148	6.179* *
$\Delta \ln FD_t$	5.609**	1.591	-	2.383	2.413	1.401	2.188	5.609* *
$\Delta \ln TO_t$	4.760**	6.336* *	8.031* *	-	4.710* *	3.536* *	2.982	4.300* *
$\Delta \ln EG_t$	1.300	3.756	5.845** *	1.847	-	-	-	1.300
$\Delta \ln SG_t$	1.765	1.071	3.940	0.936	-	-	-	1.765
$\Delta \ln PG_t$	0.087	2.508	2.166	1.041	-	-	-	0.087
$\Delta \ln G_t$	0.224	1.714	3.109	1.784	1.626	0.435	0.054	---

Note: *, ** and *** denote the significance at the 1, 5 and 10 per cent level, respectively.