Journal of Business Economics and Management
ISSN 1611-1699 / eISSN 2029-4433
2020 Volume 21 Issue 1: 1–22
https://doi.org/10.3846/jbem.2019.11321

THE ECONOMY-ENERGY-ENVIRONMENT NEXUS IN IMF'S TOP 2 BIGGEST ECONOMIES: A TY APPROACH

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Received 03 April 2019; accepted 01 August 2019, first published online

Abstract. This paper assesses the relationship between carbon emissions, economic growth and, energy consumption, in USA and China from the perspective of Granger causality, in a multivariate framework controlling for financial development, urbanization, and trade openness. Econometric techniques employed include unit root tests, Toda and Yamamoto Granger causality, and generalized impulse response and variance decomposition analysis for the time horizon 1980–2017. Test results indicate that governments of the USA and China cannot implement sturdier strategic energy policies in the long run without inhibiting the growth of the economy because of the bidirectional causative linkage between economic growth and energy use. A causal link does not exist between carbon emissions and financial development for both countries. Nevertheless, in the USA, there exists a unidirectional Granger causality controlling from energy consumption to financial development. In both economies, urbanization Granger causes CO_2 emissions and energy use but the reverse does not hold. An upsurge in energy consumption and carbon emissions will lead to a surge in trade openness but not vice versa for China. A noteworthy result is that there is a substantiation of unidirectional causality from energy consumption to carbon emissions in both countries. In the USA, impulse response and variance decomposition analysis disclosed the effect of financial development is projected to have diminutive magnitude whiles in the future, energy use, economic growth, trade openness, and urbanization would influence carbon emissions significantly. The impacts of trade openness and financial development are expected to be of little importance in China. The general findings implied that urbanization, economic growth, and energy consumption influenced CO_2 emissions significantly in the USA and China. Understanding these similar and contrasting situations is essential to reaching a global agreement on climate change affecting IMF's top 2 biggest economies.

Keywords: sustainable growth, energy-environment nexus, financial development, urbanization, trade, USA, China.

JEL Classification: E00, Q01, P18.

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Introduction

In 2014, the Intergovernmental Panel on Climate Change reported that the utmost critical atmospheric setback of this current time is global warming and it is being caused by the ever-growing concentration of greenhouse gases such as carbon dioxide (CO_2) emissions due to economic activity, and energy usage among others. Because the emissions primarily are the aftermath of fossil fuels consumption, reduction in energy consumption appears to be the rational approach of tackling the environmental setback. Nevertheless, as a result of the potential undesirable impact on economic growth, reducing energy consumption is probably considered as the "less trekked path". Moreover, if the Environmental Kuznets Curve (EKC) theory is applicable to income and carbon emissions linkage, economic growth by itself could be an answer to the environmental deterioration setback (Apergis & Ozturk, 2015; Shahbaz & Sinha, 2019). Certainly, budding and advanced countries should relinquish economic growth (Saidi & Hammami, 2015). Economies may resort to various policies in tackling global warming contingent on the sort of linkages between carbon emissions, economic growth, and energy usage (Esso & Keho, 2016; Temiz Dinç & Akdoğan, 2019). Therefore, the emissions-consumption-economic growth relationship must be investigated painstakingly for all countries to attain sustainable development.

In recent times, the decline in the quality of the environment has attained worrying heights and elevated apprehensions about climate change and global warming. As a result, parallel research work on examining the linkage between economic growth and the environment has been pursued. The first strand of literature provides empirical evidence on the emissions and economic growth linkage. The studies on environmental pollutants and economic growth primarily emphasize on the evaluation of the presence of EKC (Lau, Choong, & Ng, 2018; Springer, Evans, Lin, & Roland-Holst, 2019). The results of these studies are nevertheless inconsistent and researchers have unsuccessfully proven the inverted U relationship with a practical dataset.

The second strand of existing energy literature tackles the causal relationships between energy use and economic growth. Numerous research works have examined the relationship between economic growth and energy consumption employing datasets from various economies and regional blocs from the time when (J. Kraft & A. Kraft, 1978) conducted his groundbreaking study (see for example, Gurgul & Lach, 2011; M. Bhattacharya, Paramati, Ozturk, & S. Bhattacharya, 2016). The empirical results of current energy literature are ambiguous as a result of the utilization of varied econometric methods, for example, simple regressions, bivariate causality, panel cointegration, correlation analysis, vector error correction modelling among others to ascertain the causality path between economic growth and energy consumption (Shahbaz & Lean, 2012). These studies are subjected to the omitted variable bias.

The fusion of environment and economic growth in the framework of EKC and economic growth-energy consumption nexus literature have created another cluster of literature which focuses on the linkage between carbon emissions, economic growth, and energy consumption (Farhani, Mrizak, Chaibi, & Rault, 2014; Naminse & Zhuang, 2018). These studies under the third strand produced mixed results. They suffer from omitted variables and the use of debatable proxies to define particularly financial development (Shahbaz & Lean, 2012; Bekhet, Matar, & Yasmin, 2017) and other variables. The proxies used as financial development indicators do not account for the intricate multidimensional characteristics of financial development.

Tiba and Omri (2017) offers an excellent literature review on the emissions-energy-growth linkage and argued that comprehending the relationship between environmental quality, economic growth and energy consumption is the bedrock for new acumens on strategic environmental and energy policies and becomes the foundation for comprehensive economic policies and being coherent with environmental targets and energy policy objectives. With this in mind, the main aim of this study is to examine the temporal linkage between CO_2 emissions, economic growth, and energy consumption in International Monetary Fund's (IMF) top 2 biggest economies from the viewpoint of Granger causality, in a framework of a multivariate nature controlling for urbanization, financial development and trade openness by utilizing the Toda and Yamamoto (TY henceforth) (Toda & Yamamoto, 1995) approach.

The input of this study to the parallel literature is two-fold: In principle, the authors introduce an appropriate measurement of financial development by employing IMF's financial development index, which summarizes how financial firms and financial markets are in relation to their access, depth, and efficiency. Secondly, very few research papers include trade openness, urbanization, and financial development into the econometric model as additional time series variables. This paper to the best of authors' knowledge is the first to provide comparative information on the effect of energy use, economic growth, urbanization, financial development, and trade on carbon emissions for USA and China, forming the basis for sound economic and energy policies for both countries to reduce carbon emissions. This approach would tackle the biasness of an omitted variable that earlier research works encountered.

USA and China provide a stimulating arena to research for several reasons especially given the current trade war between both countries. These countries occupy the top 2 spots of IMF's world's biggest economies with USA being at the forefront of developed economies and China, a developing economy. China has certain characteristic qualities of economic growth and has achieved notable economic development throughout the last few decades (1990–2018) with a yearly average economic growth rate of 6–9%. The economy of China is the second biggest only next to the USA since 2015 according to the IMF. The general economic indicators in China with regards to total Gross Domestic Product will surpass that of the USA in the near future. China commenced its accessible policy in the late 1970s, so adequate data are available for researchers to assess the influence of economic growth, energy use, and other relevant alternative variables on CO_2 emissions.

This study is reliant on econometric techniques that provide possible answers to the procedural problems stated in Stern (2004). The TY procedure removes the necessity for conducting pre-tests for cointegration, consequently evades pre-examination bias and is appropriate for any arbitrary integration level of the economic variables employed.

This paper is organized as follows[1]: in the next sections, the econometric model and

[1] To conserve space, the literature review section is omitted. Please refer to Tiba and Omri (2017) and Mardani, Streimikiene, Cavallaro, Loganathan, and Khoshnoudi (2018) for an extensive literature review.

approach are discussed. Dataset and unit root tests are presented. Granger causality test, generalized impulse response and variance decomposition are shown in subsequent sections. The last section offers concluding remarks and recommendation.

1. Econometric model and approach

1.1. The model

To analyze the temporal linkage between carbon emissions, energy consumption and economic growth, which is a blend of EKC and energy-economic growth studies, authors use an analogous approach suggested in (Arouri, Ben Youssef, M'henni, & Rault, 2012). The temporal linkage existing between the aforementioned variables is presented below:

$$CO_{2t} = \alpha + \beta_1 GDPc_t + \beta_2 GDPc_t^2 + \beta_3 CONS_t + \varepsilon_t. \quad (1)$$

All times series variables are in natural logarithm. This conversion was applied to tackle heteroscedasticity problem between the time series variables. The subscript t represents time. CO_2 is per capita total carbon emissions from the use of energy (metric tons). $GDPc$ and $GDPc^2$ or GDP^2c are per capita real GDP and square of per capita real GDP, respectively. $CONS$ denotes per capita total primary energy consumption. β_1, β_2 and β_3 are coefficients of per capita total CO_2 emissions with regards to per capita real GDP, squared per capita real GDP and per capita total primary energy consumption, correspondingly. According to EKC theory, it is anticipated that $\beta_1 > 0$ and $\beta_2 < 0$. It is expected that an upsurge in energy use lead to an increase in CO_2 emissions $(\beta_3 > 0)$.

Financial development exemplifies the definite level of financial resources accessible for industrious purpose and conduits funds to projects via banks and financial markets (Sadorsky, 2010). Financial development contributes to economic development by enhancing investment via legal dealings. The effect of financial development on economic growth and thus on energy demand is positive due to a higher standard of living (Sadorsky, 2010). Financial development profits producers through the availability of inexpensive loans, which leads to purchases of advanced equipment thereby increasing the demand for energy. When the share of GDP of private and domestic credit is used as a proxy for financial development, results signify that energy use increases when financial development increases. Jalil and Feridun (2011) used China as a test study and their findings indicated the coefficient of financial development is negative, implying that financial development is not being pursued at the cost of the environment. Jalil and Feridun (2011) reported that financial development lessens carbon emissions whereas Zhang and Cheng (2009) found the reverse in these two pieces of research on China. Yuxiang and Chen (2011) discussed that an economy with a more established and comprehensive financial structure would facilitate industries to embrace and utilize innovative technologies that are less carbon exhaustive.

Generally, the literature on the linkage between CO_2 emissions and financial development indicate diverse findings although a chunk of the studies back the assertion that higher level of financial development is positively related with deteriorating intensities of carbon emissions. Consequently, financial development could be controlled and explored in the above regression model. As seen from the literature, there are no studies for the comparison of the IMF's top 2 biggest economies on this issue within the same time horizon using the well-defined financial development index from the IMF. Thus, this research aims to fill this gap.

In ecological modernization theory, urbanization is the progression of social change deemed as one significant indicator of modernization. It is said that environmental problems may arise from low to intermediate phases of growth. Though urbanization converses in the context of economic transformation, it is a demographic indicator that upsurges urban density and alters the organization of human behaviour, thus affecting energy consumption (Barnes, Krutilla, & Hyde, 2005). The urban environmental transition theory primarily deliberates the sorts of urban environmental matters and their development. It proposes that urban environmental problems differ with respect to phases of economic growth. In the light of this, the percentage of urban population to the total population can also be controlled in the econometric model mainly because urban cities in most economies are budding at a higher rate than the countrywide average, which places an undue burden on urban resources and the environment at large. Specifically, in emerging and transition countries, members of the workforce are migrating from rural to urban regions for opportunities, education, jobs, and healthcare. Urban population growth can be regarded as an alternative source of environmental pollution (Kasman & Duman, 2015).

International trade instigates movement of intermediary and final products for both consumption and further production process. The neoclassical model theoretically describes how trade liberalization magnifies both clean and dirty productions as a result of disparities in income. The division implies that the environmental impacts of trade opening on high and low-income countries are the opposite (Taylor & Copeland, 2001). The impact of trade openness is dependent on the strategies implemented in an economy (Shahbaz, Muhammad, Hye, Tiwari, & Leitão, 2013). One school of thought reasoned that international trade offers an avenue to economies to have access to international markets, which bolsters the market share among economies (Shahbaz & Lean, 2012). This results in competition between economies and increases the efficacy of using scarce resources and emboldens importing green technologies to lower carbon emissions. Another faction argued that the depletion of natural resources due to international trade increases carbon emissions (Farhani et al., 2014). An upsurge in consumption and production as a result of international trade is part of the causal factors of environmental degradation. So, trade openness could be controlled in the EKC model.

Overall, the inclusion of financial development and urbanization in the above regression can be an answer to the omitted variable bias problem in the econometric model. Therefore, the modified quadratic Environmental Kuznets Curve model pursued in this study is presented as follows:

$$\mathrm{CO}_{2t} = \alpha + \beta_1 GDPc_t + \beta_2 GDPc_t^2 + \beta_3 CONS_t + \beta_4 URB_t + \beta_5 FD_t + \beta_6 TR_t, \tag{2}$$

where FD denotes financial development index obtained from IMF, URB is the share of urban population and TR denotes trade openness. The signs β_4, β_5 and β_6 are expected to be positive.

Econometric method

To achieve the objectives of this study, the following processes were taken in a step-by-step manner. In the first step, authors pursue the TY approach to test for Granger causality. In the second major step, the authors observe how a shock to one time series variable affects alternative variable and how extensive the effect of the shock persists in the short run by utilizing generalized impulse response functions (Koop, Pesaran, & Potter, 1996).

Toda-Yamamoto procedure

If the time series variables were identified to be integrated of order one without cointegration, a Vector autoregression (VAR) in first-order differences of the variables could be implemented. An Error correction model (ECM) could be implemented in case the time series were identified as cointegrated. Therefore, whether the time series variables are cointegrated, integrated, or (trend), stationarity characteristics of the econometric variables are subjected to pre-tests. Toda and Yamamoto provided proof in his study that in a finite sample, pre-examinations must be executed for cointegration ranks before employing VAR. For that reason, causality inferences in ECM are susceptible to strict pre-test biasness. The augmented VAR method suggested by Toda and Yamamoto has desirable practical allure because it applies to any arbitrary level of integration. If one is unsure of the order of integration of time series variables, the TY procedure is being conducted on the conservative side. TY procedure is attractive due to its minute size distortion and its stability for samples that are characteristic for econometric variables. Following (Appiah, 2018; Salahuddin et al., 2019), authors employ TY approach to assess the energy-environment-economic growth-financial development-urbanization-trade nexus in a comparative study of USA and China. The steps for TY procedure are as follows:

1) Evaluate each time series variable to define their maximum order of integration $\boldsymbol{m}$ by performing unit root tests. Thus, if there exist two economic time series variables and one is $\boldsymbol{I}(2)$ and the other is $\boldsymbol{I}(3)$, then $\boldsymbol{m} = 3$;
2) Construct a VAR model in the levels of the economic data and not the difference data, irrespective of the orders of integration of the different time series variables;
3) Determine the optimal lag length $\boldsymbol{p}$ for the time series variables in the VAR. Because the true lag length $\boldsymbol{p}$ is not identified, one can deduce it by using Hanna-Quinn Information Criterion (HQ), Final Prediction Error (FPE), etc;
4) Ensure that the VAR is well specified. Make sure that no serial correlation exists in the residuals. If necessary, increase $\boldsymbol{p}$ until every autocorrelation problem is tackled;
5) Estimation of the lag-augmented $\boldsymbol{VAR}(\boldsymbol{p}+\boldsymbol{m})$ model:

$$V_t = \alpha + \beta_1 V_{t-1} + \beta_2 V_{t-2} +, \ldots, + \beta_p V_{t-p} + \beta_{p+m} V_{t-p-m} + \varepsilon_t \, , \tag{3}$$

where, α is a vector of constant, β_t is a coefficient matrix, and ε_t is white noise residuals.

2. Dataset and Unit root tests

2.1. Data

The dataset in this paper comprises 6 time series variables. They are per capita total CO_2 emissions from the consumption of energy in metric tons (Mt), per capita total primary energy consumption in British Thermal Unit (BTU), per capita GDP in constant 2010 US$, financial development index, trade (% GDP) and urban population (% total) from USA and China over the time horizon 1980–2017. Data for both countries were acquired from U.S Energy Information Administration, International Monetary Fund, and World Development Indicators of World Bank.

Descriptive statistics of carbon emissions, energy use, real per capita GDP, financial development, urbanization and trade openness are displayed in Table 1. For all the variables, U.S.A has the highest mean values (except for trade openness) with the highest volatility in per capita real GDP and financial development. China has the highest volatility in terms of per capita CO_2 emissions, energy consumption and urbanization and trade.

Table 1. Descriptive statistics of econometric variables

		CO_2	GDPc	CONS	URB	FD	TR
USA	Mean	19.3775	41745.6843	328405135.8	78.0063	0.7278	23.1181
	Std. Dev.	1.4084	7754.1484	15393934.31	2.7585	0.1711	4.3667
China	Mean	3.8658	2421.5816	47257412.74	36.2726	0.4163	36.8824
	Std. Dev.	2.2147	2112.5319	29538010.04	11.9155	0.1404	13.9860

Note: Std. Dev., CO_2, $GDPc$, $CONS$, URB, FD and TR denotes standard deviation, per capita CO_2 emissions, per capita real GDP, per capita energy consumption, urbanization, financial development and trade openness respectively.

2.2. Unit root tests

The first step of TY procedure requires conducting unit root tests to determine the stationarity properties and maximal order of integration of variables. This paper utilizes Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) unit root tests. The results of the unit root tests are reported in Table 2. Maximum integration order for variables pertaining to the USA and China do not exceed 2, thus $m = 2$. Because all variables do not seem to be integrated of order one, cointegration tests may not be applicable as the TY approach does not require the information on cointegration.

Perron (2006) suggested that several econometric variables with structural discontinuity exhibit properties of stationary variability. The concept of the structural break must be considered when utilizing unit root tests. ADF, PP and KPSS tests offer prejudiced and spurious outcomes as a result of not having knowledge about points of structural break ensued in the variables. Therefore, Zivot and Andrews (1992) (henceforth ZA) under the alternative hypothesis proposed a unit root testing technique permitting a projected break in the trend function. Zivot and Andrews proposed the following cases in the presence of a structural breakpoint to test the stationarity characteristics of time series variables:

Table 2. Unit root tests

	USA			China		
	ADF	PP	KPSS	ADF	PP	KPSS
Levels: Intercept	t-Stat. (SIC lag)	Adj. t-Stat.	LM-Stat.	t-Stat.(SIC lag)	Adj. t-Stat.	LM-Stat.
CO_2	0.1095 (0)	0.1007	0.4384***	–0.5969 (1)	–0.0739	0.6983***
GDPc	–1.5469 (1)	–1.7322	0.7280***	–0.6437 (2)	–0.3509	0.7280***
GDP2c	–1.5696 (1)	–1.8035	0.7337***	–0.9982 (2)	–0.7870	0.7337***
CONS	0.9303 (0)	–0.9649	0.3128***	–0.6504 (1)	–0.2419	0.7197***
URB	–1.3592 (1)	–0.6823	0.7314***	–1.0231 (1)	–2.6267*	0.7462
FD	–2.0311 (5)	–2.5639	0.6740***	–2.6774* (0)	–2.6820*	0.8297
TR	–0.9043 (0)	–0.9043		–2.2431 (1)	–2.8368*	0.6179***
Levels: Intercept & Trend						
CO2	–0.6990 (0)	–0.6996	0.1768***	–1.9929 (2)	–1.7808	0.1504***
GDPc	–1.6615 (1)	–1.2031	0.1858***	–3.0751 (3)	–2.1892	0.1858***
GDP2c	–1.4560 (1)	–1.0125	0.1712***	–3.5155* (3)	–1.9792	0.1712***
CONS	–1.2832 (0)	–1.2979	0.1772***	–1.6665 (1)	–1.8373	0.1289***
URB	–3.1252 (1)	–1.1402	0.1326***	–0.1270 (1)	0.4043	0.1376***
FD	–0.7206 (5)	–1.4814	0.1912***	–4.1683** (0)	–4.1764**	0.1009***
TR	–3.2046*(0)	–3.2046*	0.0755***	–1.3704 (1)	–1.3401	0.1772***
First difference: Intercept						
CO_2	–5.1993***(0)	–5.1614***	0.2710***	–3.6702***(0)	–3.7126***	0.1574***
GDPc	–4.1550***(0)	–4.0656***	0.3571***	–4.2167***(1)	–3.4537***	0.3571***
GDP2c	–4.1209***(0)	–4.0572***	0.3128***	–4.1665***(1)	–3.4244**	0.3128***
CONS	–5.5917***(0)	–5.6398***	0.1420***	–4.4829***(0)	–4.4455***	0.1082***
URB	–1.8720 (1)	–1.6118	0.1593***	–1.5623 (0)	–1.7723	0.4553***
FD	–3.2275***(6)	–5.1181***	0.3497***	–6.2563***(0)	–6.2563***	0.1471***
TR	–6.0404***(0)	–6.0644***	0.1028***	–4.9111***(0)	–4.8944***	0.4498***
First difference: Intercept & Trend						
CO_2	–6.6311*** (1)	–5.4269***	0.1023***	–3.5378* (0)	–3.5796**	0.1237***
GDPc	–4.3475*** (0)	–4.1112**	0.0617***	–4.1916** (1)	–3.3907*	0.0617***
GDP2c	–4.3649*** (0)	–4.1363**	0.0682***	–4.2433** (1)	–3.4565*	0.0682***
CONS	–6.5883*** (1)	–5.6694***	0.0832***	–4.3865*** (0)	–4.3416***	0.1029***
URB	–9.9303*** (9)	–1.6558	0.1414***	–1.8638 (0)	–2.1568	0.1332***
FD	–3.8415***(4)	–5.5698***	0.0486***	–6.3179***(0)	–6.3179***	0.1120***
TR	–5.9467***(0)	–5.9632***	0.1014***	–5.3337***(0)	–5.2965***	0.0688***
Second difference: Intercept						
URB	–7.4243***(9)	–4.1979***	0.1494***	–5.0719***(0)	–5.0719***	0.1310***
Second difference: Intercept & Trend						
URB	–5.5589***(9)	–4.1816**	0.0947***	–4.9967***(0)	–4.9967**	0.1334***

Note: All time series variables are in natural logarithm except for financial development index, lag lengths are determined via Eviews automatic selection for Schwarz Information Criterion (SIC) and are in parentheses. Superscripts ***, **, and * denote significance at 1, 5, and 10% respectively. The null of ADF and PP are unit roots. KPSS null hypothesis is stationarity.

$$\text{Case A: } \Delta y_t = \alpha + \alpha y_{t-1} + bt + cDU_t + \sum_{i=1}^{k} d_i \Delta y_{t-i} + \varepsilon_t , \tag{4}$$

$$\text{Case B: } \Delta y_t = b + by_{t-1} + bc + bDT_t + \sum_{i=1}^{k} d_i \Delta y_{t-i} + \varepsilon_t , \tag{5}$$

$$\text{Case C: } \Delta y_t = c + cy_{t-1} + ct + dDU_t + dDT_t + \sum_{i=1}^{k} d_i \Delta y_{t-i} + \varepsilon_t , \tag{6}$$

where Δy_t is the differentiation of variable y, y_{t-1} is one order lagged variable, y_{t-i} is *i* order lagged variable, and ε_t is white noise residual. DU_t is a dummy variable and indicating mean shift occurred at each point with time break and trend shift variables are represented as DT_t. Therefore,

$$DU_t = \begin{cases} 1, \text{ if } t > TB \\ 0, \text{ if } t < TB \end{cases} \quad \& \quad DT_t = \begin{cases} t - TB, \text{ if } t > TB \\ 0, \quad \text{ if } t < TB \end{cases}.$$

Case A permits one-time alteration in time series at the intercept and Case B gives way for one-time alteration in the slope of trend constituent. Case C allows one-time alteration in trend and intercept function of time series. So, ZA unit root test is employed in this study to estimate the order of integration of the variables, and results are displayed in Table 3.

Table 3. ZA Unit root test results

	USA		China	
	Levels			
	t-stastic (Lag length)	Time Break (Break location)	t-stastic (Lag length)	Time Break (Break location)
CO_2	–3.2782 (3)	2008 (A)	–4.0529 (2)	2003 (A)
GDPc	–3.9108(1)	2008 (A)	–4.2493* (3)	1990 (B)
GDP2c	–3.7571 (1)	2008 (A)	–5.0584* (3)	2009 (C)
CONS	–3.3524 (3)	2008 (A)	–3.2053 (2)	1996 (C)
URB	–6.4767***(1)	1991 (A)	–4.4105* (1)	2011 (B)
FD	–3.3062 (0)	1995 (A)	–4.6060*(0)	1991 (A)
TR	–3.9262 (0)	2011 (B)	–4.8574 (0)	2003 (C)
First difference				
CO_2	–5.8592***(2)	2008 (C)	–4.6979**(0)	2010 (B)
GDPc	–4.5607 (0)	2007 (A)	–4.2240* (4)	2011 (B)
GDP2c	–4.6301* (0)	2007 (A)	–4.1523* (4)	2011 (B)
CONS	–7.2839*** (1)	1990 (C)	–4.1465 (1)	2003 (C)
URB	–3.3651	1992 (B)	–6.8074*** (1)	2005 (B)
FD	–4.3669(4)	1995 (A)	–10.7247*** (1)	2011 (B)
TR	–6.9031***(0)	1988 (B)	–6.4782***(0)	2007 (B)

End of Table 3

	USA		China	
	Levels			
	t-stastic (Lag length)	Time Break (Break location)	t-stastic (Lag length)	Time Break (Break location)
Second difference				
GDPc	–6.5144*** (2)	2010 (A)	N/A	N/A
CONS	N/A	N/A	–5.6893*** (4)	1993 (A)
URB	–5.6289***(0)	1992 (C)	N/A	N/A
FD	–6.1970***(4)	1997 (C)	N/A	N/A

Note: The alphabets in parentheses specify the Case A, B and C of ZA unit root test. Superscripts ***, **, and * denote significance at 1, 5, and 10% respectively.

For the USA, Zivot and Andrews unit root tests show that all variables (with the exception of *GDPc*, *URB*, and *FD*) are of the first order of integration at a different critical level, although *GDPc*, *URB* and *FD* time series variables are $I(2)$ at 1% critical level. Therefore, the maximum order of integration m is 2. In the case of China, ZA unit root tests show that each of the econometric variables (with the exception of *CONS*) are $I(1)$ at a different critical level, although *CONS* variable is $I(2)$ at 1% critical level. Therefore, the maximum order of integration m for China is also 2.

3. Causality tests

All the time series variables are not integrated of the same order according to the results from Table 2 and 3. Therefore the TY approach for assessment of Granger causality is the most suitable approach. As indicated in the steps for TY approach, the optimal lag length p of the series in the VAR must be determined. Five lag length criteria to choose the lag length are conducted. They are Hannan-Quinn Information Criterion (HQ), sequential modified LR test statistic (LR), Akaike Information Criterion (AIC), Final Prediction Error (FPE), Schwarz Information Criterion (SIC). The selection of the lag length results of the VAR model is accessible in Table 4.

For the USA, LR recommends a lag length of 2, FPE, AIC and HQ point out that $p=3$ whereas the optimal lag length of VAR via SIC is 1. Conversely, there are problems when authors observe the residuals and utilize LM test for serial independence against $AR(k)/MA(k)$, for, $k=1, ...,15$. Authors overcome serial correlation (at least at the 5% sig. level) if the optimum lag length is $p=2$ (Refer to Table 5). The projected model is dynamically stable because all roots are inside the unit circle after determining the inverse roots of AR characteristic polynomial (Refer to the left side of Figure 1).

In the case of China, LR, FPE, AIC and HQ propose a lag length of 2 but the optimum lag length of VAR according to SIC is 1. The serial correlation is non-existent (at least at the 5% sig. level) when the optimum lag length is $p=2$ after examining residuals and applying the LM test for serial independence against $AR(k)/MA(k)$, for, $k=1, ...,15$. The assessed model is dynamically stable because all roots are inside the unit circle after determining the inverse roots of AR characteristic polynomial (Refer to the right side of Figure 1).

Table 4. Results of lag length selection

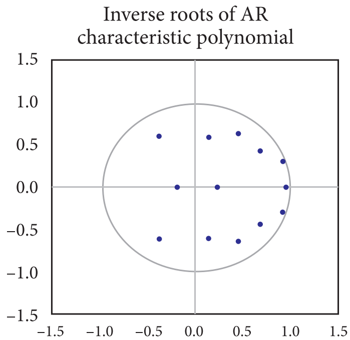
USA	Lag	0	1	2	3
	LogL	551.1331	932.559	1018.062	1106.721
	LR	N/A	588.4856	97.71790*	65.86063
	FPE	7.40E-23	4.41E-31	7.82E-32	2.52e-32*
	AIC	–31.09332	–50.08908	–52.17498	–54.44118*
	SC	–30.78225	–47.60053*	–47.50893	–47.59765
	HQ	–30.98594	–49.23003	–50.56426	–52.07880*
China	Lag	0	1	2	
	LogL	341.3352	786.6794	872.8954	
	LR	N/A	681.1147	96.35899*	
	FPE	6.79E-18	5.41E-28	8.98e-29*	
	AIC	–19.66678	–42.98114	–45.17032*	
	SC	–19.35253	–40.46714*	–40.45656	
	HQ	–19.55961	–42.1238	–43.56279*	

Note: * specifies lag order chosen by the criterion. Maximum lag length of the VAR is 3 and 2 for USA and China respectively. N/A means not applicable.

Table 5. Autocorrelation LM test

USA			China		
Lags	LM-Stat	Prob.	Lags	LM-Stat	Prob.
1	60.61651	0.1234	1	89.4584	0.0512
2	53.10713	0.3189	2	74.66134	0.0605
3	49.53237	0.4519	3	54.2838	0.2801
4	49.62126	0.4483	4	50.53525	0.4127
5	59.19393	0.1510	5	46.67653	0.5678
6	34.76206	0.9380	6	54.48416	0.2738
7	59.53541	0.1440	7	38.66391	0.8553
8	48.25507	0.5032	8	33.44602	0.9562
9	50.74686	0.4045	9	33.25089	0.9585
10	43.40139	0.6987	10	34.62312	0.9401
11	56.37558	0.2185	11	38.1802	0.8680
12	44.68575	0.6485	12	53.9152	0.2920
13	55.47559	0.2438	13	43.07017	0.7112
14	63.94263	0.0743	14	48.19092	0.5059
15	49.66381	0.4467	15	62.17535	0.0979

Note: Null Hypothesis: no serial correlation.



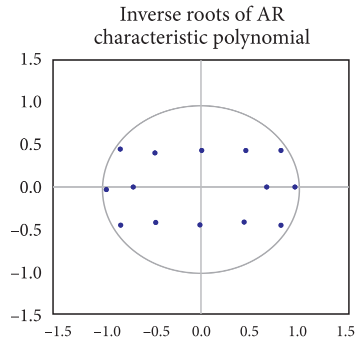


Figure 1. USA (left) and China (right): AR roots graphs for Inverse Roots of AR characteristic polynomial

Hence, for USA and China, estimation of the augment $VAR(4)(p+m=4)$ with $V_t = \left(C0_{2t}, GDPc_t, GDPc_t^2, CONS_t, FD_t, URB_t, TR_t\right)'$ is pursued and this study conducts various diagnostic tests to assess the robustness of $VAR(4)$. Diagnostic tests results are displayed in Table 6.

Table 6. Diagnostic test results for augment VAR model

	Jarque-Bera Test	Adjusted R^2	White Test	ARCH LM	RAMSEY RESET
	USA				
CO_2	2.2829	0.9537	24.2046	2.4031 (1)	0.6789
GDPc	0.5892	0.9951	22.5326	1.0431 (1)	0.1781
GDP2c	0.2719	0.9971	22.5341	1.0114 (1)	0.2521
CONS	0.5972	0.8981	22.4369	2.1132 (3)	0.1596
URB	1.6258	0.9996	24.0561	1.2514 (3)	0.8933
FD	1.8142	0.9603	28.3865	0.9843 (1)	0.7495
TR	0.2133	0.9449	31.2853	1.4322 (1)	0.4949
	China				
CO_2	5.7450	0.9922	24.6805	0.4995 (1)	0.2773
GDPc	1.6237	0.9998	28.7533	1.3120 (3)	0.1441
GDP2c	0.7619	0.9998	28.6688	1.2749 (3)	0.1546
CONS	12.3580	0.9951	23.4796	0.4082 (1)	4.9297
URB	4.4207	0.9999	28.6621	1.2721 (3)	0.3557
FD	4.1833	0.9651	28.7823	1.3251 (1)	0.1362
TR	6.3795	0.9539	30.5719	3.1713 (1)	0.1348

Note: The null hypothesis for Jarque-Bera is normality. The null hypothesis for ARCH LM is no ARCH up to the selected lag. The null hypothesis for White test is no heteroscedasticity. Lag lengths are selected by SIC and indicated in parentheses. Null hypothesis for the Ramsey RESET test is no specification errors with one fitted term using LR.

Diagnostic test results for both USA and China demonstrate that there is no severe negligence of heteroscedasticity or normality assumptions. Additionally, ARCH effect is nonexistent. All residuals are not violating normality according to Jarque-Bera test results indicated above. Autoregressive conditional heteroscedasticity is nonexistent as shown by ARCH Lagrange multiplier tests. No evidence of heteroscedasticity for all equations in the VAR according to White tests. From Table 6, Ramsey RESET test results specify that the time series appears to be stable. For China, while Ramsey RESET test results show that $CONS$ variable appears to be exhibiting instability, stability violation was not confirmed by CUMSUM and CUMSUM square tests. The $VAR(4)$ for both countries exhibits properties of stability with all unit roots in the unit circle. Adjusted R^2 values are high and marginally lower than unadjusted R^2. So, the descriptive power of all VAR equations is robust. Contented with the diagnostic results of the VAR models, authors conduct Granger causality tests.

3.1. Granger causality

The Granger causality procedure checks the existence and path of causality between time series variables. Test results of the Granger causality method can be unidirectional, bidirectional, or no mutual neutral link. The TY approach permits for the implementation of Granger causality tests, without the necessity to test for cointegration and deducing the cointegrating equation. The dissimilarity from the conventional Granger causality tests is that in TY approach, instead of all lags this study uses a modified Wald test on the first p lags. Results of TY based Granger causality tests are summarized in Table 7.

According to Table 7, there is a bidirectional Granger causality from per capita real GDP/square of per capita real GDP to per capita total carbon dioxide emissions at the 5% significant level in the USA. This result is in line with that of Dogan and Turkekul (2016). Per capita total primary energy consumption Granger causes per capita real GDP/square of per capita real GDP in the long run and with the order reversed. That is, a surge in economic growth will result in an increase in total primary energy use and vice versa. This means that the conservative energy policy cannot be implemented in the long run without inhibiting economic growth in the USA. This result tallies with that of Shahbaz et al. (2013) in the case of Indonesia. Another significant result is that urbanization Granger causes per capita real GDP/square of per capita real GDP, per capita total carbon dioxide emissions, and per capita total primary energy consumption in the long run, although the reverse is not true. There is a unidirectional Granger causality running from trade openness to urbanization. An increase in trade openness will cause an increase in urbanization. Urbanization Granger causes CO_2 emissions and energy use in a unidirectional manner. Trade openness also Granger causes carbon emissions in a unidirectional manner. There is also a unidirectional Granger causality running from energy consumption to financial development. An upsurge in energy use will cause an increase in financial development. Hence, knowledge of energy consumption improves the forecasts of financial development index, but the reverse does not hold.

Another important result is that per capita total primary energy consumption Granger causes the per capita total carbon dioxide emissions in a unidirectional pattern. That is an increase in energy use results in a surge in carbon emissions. Therefore, an apt way to decline carbon emissions is by decreasing energy consumption in the USA.

Table 7. TY Granger causality test results

Dependent Variables	Independent Variables						
	USA						
	CO_2	*GDPc*	*GDP2c*	*CONS*	*URB*	*FD*	*TR*
CO_2	–	4.1326**	4.2331**	2.2527*	4.6308**	0.9820	3.7336**
GDPc	6.2288**	–	10.8825***	3.772832*	8.3678***	0.1640	13.9721***
GDP2c	6.1814**	10.2639***	–	3.5648*	8.2166***	0.1031	14.2985***
CONS	2.6319	3.1673*	3.2830*	–	3.2994*	1.5595	2.1210
URB	0.0103	0.5218	0.4854	1.5067	–	0.1988	3.5236*
FD	0.1199	0.3081	0.3064	0.0005*	0.2049	–	1.9680
TR	1.9347	0.0997	0.1182	2.1147	0.0158	2.6526	–
	China						
	CO_2	*GDPc*	*GDP2c*	*CONS*	*URB*	*FD*	*TR*
CO_2	–	1.9180	1.9449	1.6920*	9.3942***	0.7044	0.9636
GDPc	1.0967	–	0.1971	2.8276*	0.2739	0.0083	20.0206***
GDP2c	1.0106	0.0930	–	3.0281*	0.2647	0.0052	20.2057***
CONS	0.0237	2.1378*	2.1674*	–	9.8000***	0.3948	0.9989
URB	1.8461	2.3668	2.5521	1.6358	–	0.2548	3.7887*
FD	0.0216	0.0058	0.0106	0.5697	0.0482	–	1.3850
TR	2.8571*	4.6992**	4.9086**	8.4894***	7.1649***	0.0074	–

Note: USA: $CO_2 \rightarrow$ *GDPc/GDP2c, GDPc/GDP2c* $\rightarrow$ *CO2, GDP2c* $\rightarrow$ *GDPc, GDPc* $\rightarrow$ *GDP2c GDPc/GDP2c* $\rightarrow$ *CONS, CONS* $\rightarrow CO_2$, *CONS* $\rightarrow$ *GDPc/GDP2c, CONS* $\rightarrow$ *FD, URB*$\rightarrow$*GDPc/GDP2c, URB* $\rightarrow$ *CONS, URB* $\rightarrow CO_2$, *TR* $\rightarrow CO_2$, *TR* $\rightarrow$ *GDPc/GDP2c, TR* $\rightarrow$ *URB.*

China: $CO_2 \rightarrow$ *TR, GDPc/GDP2c* $\rightarrow$ *CONS, GDPc/GDP2c* $\rightarrow$ *TR, CONS* $\rightarrow$ *TR, CONS* $\rightarrow CO_2$, *CONS* $\rightarrow$ *GDPc/GDP2c, URB* $\rightarrow CO_2$, *URB* $\rightarrow$ *CONS, URB* $\rightarrow$ *TR, TR*$\rightarrow$*GDPc/GDP2c, TR* $\rightarrow$ *URB.*

$x \rightarrow y$ means x Granger causes y . Superscripts ***, **, and * represent significance at the 1, 5, and 10% respectively.

Results for China in Table 7 indicate that there is evidence of a unidirectional Granger causality from carbon emissions and energy use to trade openness at 10% and 1% significant levels respectively. An increase in carbon emissions and energy consumption will result in an increase in trade openness although the reverse is not true. However, there exists a bidirectional Granger causality running from per capita real GDP/square of per capita real GDP and urbanization to trade openness. So, an upsurge in GDP and urbanization results in an increase in trade openness and vice versa. Also, an increase in trade openness will lead to an increase in urbanization. The reverse does hold since the causality is bidirectional. Urbanization Granger causes carbon emissions and energy use in China. Hence, the knowledge of urbanization may improve the forecasts of carbon emissions and energy use but the reverse does not hold. There exist a unidirectional causality from energy consumption to carbon emissions in China, which matches the results obtained by Wang, Li, Fang, and Zhou (2016).

A significant result is that in China, there exists a unidirectional causality from energy use to carbon emissions. This finding coincides with the results obtained by Zhang and Cheng

(2009). Therefore, an increase in energy consumption will bring about an increase in CO_2 emissions. A suitable way of decreasing carbon emissions in China is by the reduction of energy consumption. Another important deduction is that in China, there is a bidirectional Granger causality at 10% significant level running from per capita real GDP/square of per capita real GDP to energy use. An increase in Gross Domestic Product will result in an increase in energy consumption and the reverse is true. This means that without inhibiting economic growth, conservative energy policy cannot be implemented in the long run. This outcome confirms the result obtained by (Yuan, Kang, Zhao, & Hu, 2008; Wang et al., 2016).

There is no causality between carbon emissions and financial development in USA (Dogan & Turkekul, 2016) and China. There exist bidirectional causative linkage between economic growth and energy use for both the USA and China. In both economies, urbanization Granger causes CO_2 emissions and energy use but the reverse does not hold. A significant result is that there is evidence of unidirectional causality from energy consumption to carbon emissions in both countries. The findings show that governments of the USA and China cannot implement sturdier strategic energy policies in the long run without inhibiting the growth of the economy because of the bidirectional causative linkage between economic growth and energy use. Causal link does not exist between carbon emissions and financial development for both countries.

4. Generalized impulse responses and Variance Decomposition

The TY technique is a method to assess Granger causality link between econometric variables. Nevertheless, the procedure does not offer evidence in what way each time series variable reacts to innovations in alternative time series variables, and if the shock is on a temporary or permanent basis. Generalized impulse response analysis (Koop et al., 1996) can be used to achieve this and also used in tackling the problem of orthogonality in conventional out-of-sample Granger causality tests. Figures 2–3 demonstrates the responses of carbon emissions and energy use to other time series variables in the VAR.

From Figure 2, a shock in one of the 6 time series has significant and positive initial impacts on energy use and CO_2 emissions except for the accumulated response of energy consumption to financial development[2]. The preliminary effect of energy consumption on CO_2 emissions not only is slightly higher but also persists long in the initial stages. As a shock to urbanization has a higher initial and latter impact on carbon emissions and energy consumption when compared to others. Therefore, the result of a generalized impulse response is in line with results of Granger causality tests. It's also worthwhile to remark that the effects of financial development on carbon emissions and energy consumption are increased over the time period while its preliminary impact is insignificant. It infers that financial development has positive effects on carbon emissions and energy use for the case of the USA.

In the case of China, from Figure 3, a shock in one of the six variables has mixed results in terms of initial impacts on energy use and carbon emissions. The preliminary impact of energy consumption on CO2 emissions is slightly higher and maintains a steady incre-

[2] Only accumulated responses of energy consumption and carbon emissions are presented and self-shocks are not reported to conserve space. Upon request, all omitted responses will be made available.

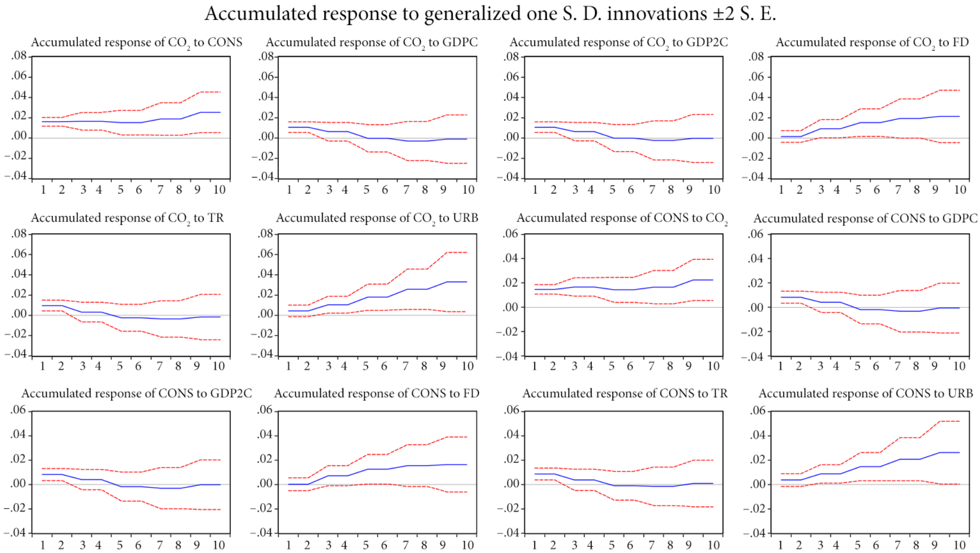


Figure 2. USA: Generalized impulse responses of CO_2 emissions and energy consumption to alternative variables

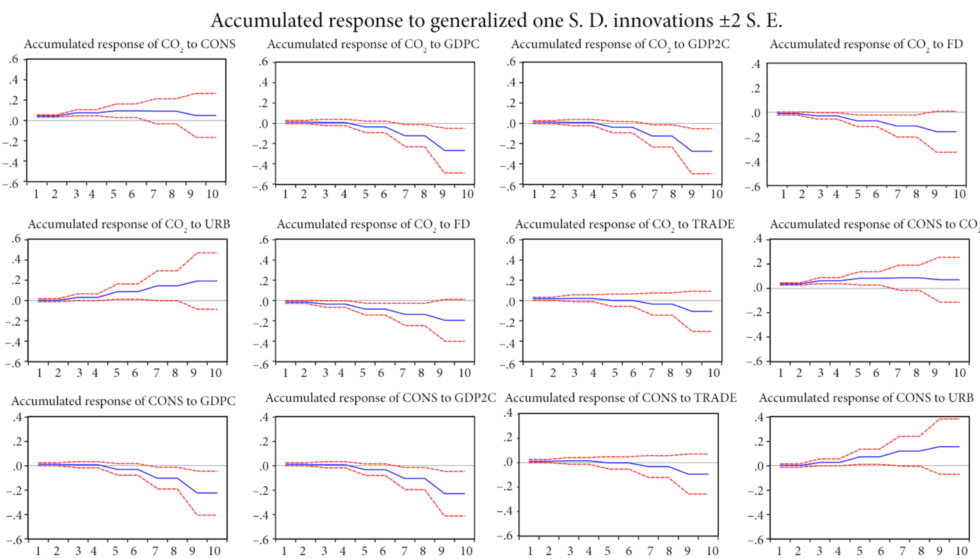


Figure 3. China: Generalized impulse responses of carbon emissions and energy use to other variables

ment until around the 8th year. A shock to financial development has the lowest initial and final impact on carbon emissions and energy consumption as compared to other variables. Therefore, the result of the generalized impulse response is in line with results of Granger causality. It is also worthwhile to observe that impacts of per capita GDP/square of per capita GDP and trade on carbon emissions and energy consumption are decreased over the time period although its initial impact is significant. Another important finding is that a shock to urbanization on energy consumption and carbon emissions has positive initial impacts and lasts longer than others. Thus, the outcome of the impulse response analysis tallies with that of the Granger tests.

Even though the generalized impulse response analysis ascertains the impact of a one standard deviation shock on the present and impending values of all the dependent time series via the dynamic component of VAR, it does not offer the enormity of such impact. So, the variance decomposition analysis is used to assess such magnitude.

Table 8. Variance decomposition of carbon emissions for the USA and China: 1980–2017

Period	S.E.	CO_2	*GDPc*	*GDP2c*	*CONS*	*URB*	*FD*	*TR*
	USA							
1	0.0168	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0168	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0215	61.9796	14.8664	0.0173	4.2933	10.3250	2.9340	5.5844
4	0.0215	61.9796	14.8664	0.0173	4.2933	10.3250	2.9340	5.5844
5	0.0242	49.4655	18.6452	3.3289	4.6548	14.1760	2.1084	7.6213
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
38	0.0358	41.8832	16.9410	20.0098	6.0487	9.4191	1.2399	4.4583
39	0.0359	41.8608	16.9515	20.0588	6.0404	9.4133	1.2522	4.4229
40	0.0359	41.8608	16.9515	20.0588	6.0404	9.4133	1.2522	4.4229
	China							
1	0.0168	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0168	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0215	61.9796	2.2933	14.8664	0.0173	5.5844	4.9340	10.3250
4	0.0215	61.9796	2.2933	14.8664	0.0173	5.5844	4.9340	10.3250
5	0.0242	49.4655	2.6548	18.6452	3.3289	7.6213	4.1084	14.1760
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
38	35.4852	0.1098	9.6810	68.6961	9.0968	10.0900	0.4898	1.8365
39	47.3866	0.0999	10.4503	68.4370	9.1580	9.4037	0.4850	1.9660
40	47.3866	0.0999	10.4503	68.4370	9.1580	9.4037	0.4850	1.9660

Test results from the variance decomposition analysis are displayed in Table 8. This research paper pursues a 40-year forecasting period. In the case of the USA, at the 5-year projecting period, approximately 50% of the one-step estimate variance in per capita total carbon dioxide emissions is characterized by its own innovations and overall about 50% is described by energy consumption, economic growth, trade openness, financial development, and urbanization. The response to own innovative shocks declines to around 42% in the long run whereas the response of per capita total carbon dioxide emissions to the shocks in energy use, economic growth, financial development, urbanization, and trade openness are expected to increase to approximately 58% from the first 5-year predicted period of approximately 50%. The findings of this research reinforce that while economic growth is prone to have a mildly strong projected impact on per capita total carbon dioxide emissions, the impact of urbanization is also probable to be apparent in the forthcoming years. Nevertheless, the forecasted influence of financial development appears not to be strong.

In the case of China, at the 5-year projected period, approximately 50% of the one-step predicted variability in per capita total carbon dioxide emissions is characterized by its own innovations and in all about 50% is characterized for by economic growth, energy consumption, financial development, trade openness, and urbanization. In the long run, the response to carbon emissions own innovative shocks decreases to a shocking 9.99% while the response of per capita total carbon dioxide emissions to the shocks in economic growth, energy consumption, financial development, urbanization, and trade openness are anticipated to ascent to 90.01% from the first 5-year forecast period of about 50% with economic growth taking a chunk of the shocks. The outcomes strengthen that while economic growth is expected to be of a very strong predicted influence on per capita total carbon dioxide emissions, the impact of urbanization and energy consumption is also probable to be apparent in the future. But, the predicted impact of trade openness and financial development appears not to be strong.

In general, findings determined that economic growth, urbanization, and energy use significantly contributed to CO_2 emissions in the IMF's top 2 biggest economies.

Conclusions

Economic growth usually accompanies increment in carbon dioxide emissions. This paper's objective is to evaluate the effect of economic growth, energy use, urbanization, trade, and financial development on carbon emissions in IMF's top 2 biggest economies using data for the time horizon of 1980–2017. Applying the TY approach, generalized impulse response and variance decomposition, this paper investigates the temporal linkages of the above mentioned time series variables for USA and China in a multivariate model.

The results show that China emits more carbon dioxide on average than in the USA. However, considering population i.e. per capita, USA dominates China in carbon emissions with a mean value of 19.3775 as compared to China's 3.8658. Total primary energy consumption and per capita total primary energy consumption in the USA are higher than China on average. This infers, considering per capita, the USA emits more carbon dioxide and has a higher energy consumption rate. China's reliance on coal consumption could be the reason why it emits more carbon dioxide on average and consumes less energy when compared to the USA. In China, coal makes up approximately 60% of total primary energy, which is not just the principal fundamental energy but also additionally the leading cause of CO_2 emissions.

The results from the Granger causality test indicate a bidirectional relationship between energy consumption and economic growth for both countries. This means that without inhibiting economic growth, governments of the USA and China cannot implement stronger conservative energy and environmental policies in the long run. The bidirectional Granger causality running from economic growth to carbon emissions hints that if the economic outputs continue to increase, the number of carbon emissions in the USA will not decline in the coming years. There is no causal relationship between carbon emissions and financial development for both countries. However, from energy consumption to financial development, there exists a unidirectional Granger causality in the USA. An increase in energy consumption will cause an increase in financial development. Urbanization Granger causes carbon emissions and energy use in both China and USA but the reverse does not hold. This is due to the fact that the growth level of cities in the USA and China are at a faster rate and workers are moving from rural areas to urban cities, which places a burden on the environment and urban resources. Growing urban population is the source of pollution in the USA and China. Trade openness also Granger causes carbon emissions in a unidirectional manner. Hence reducing trade openness seems to be an effective approach to lessen carbon emissions in the USA. A significant result is that there is a unidirectional causality from energy consumption to carbon emissions in both China and the USA. Therefore, an appropriate way of decreasing carbon emissions in both countries is by the reduction of energy consumption especially coal consumption in the case of China.

Impulse response and variance decomposition analysis disclosed that economic growth, energy use, trade openness, and urbanization would persist in impacting carbon emissions significantly into the coming years whereas the influence of financial development is anticipated to be of minute importance in the USA. For China, the impacts of trade openness and financial development are anticipated to have petite magnitude. In general, findings determined that economic growth, urbanization, and energy use significantly contributed to CO_2 emissions in IMF's top 2 biggest economies.

Policy-wise, authors recommend that major companies in the USA and China with high contamination inclination should be spurred to employ technological frameworks and energy efficiency trends to restrict carbon emissions through strict government policies and environmental laws. Specifically, Chinese industries should curb the use of coal as it's the dominant source of energy and emits more carbon dioxide. Coal gasification should be emboldened by policymakers and industry players as it provides environmental benefits at a much lower cost in tackling atmospheric build up of carbon dioxide. Informative programs should be implemented in order to educate industrial managers on the use of sustainable technologies and energy efficient practices.

Study results are limited to two countries and should be checked using different econometric methods. The approach used in this research is based on econometric techniques suitable for the characteristics of the time series variables employed. A probable future research would be to consider other methods and investigate alternative countries, which could lead to a broader understanding from an economic standpoint.

Acknowledgements

The authors thank the editor and reviewers for their comments and suggestions.

Funding

The authors acknowledge support from Management Science Project (Approval Number: 20192BAA208018) of Science and Technology Department of Jiangxi Province, China and School of Economics & Management, Jiangxi University of Science & Technology, Ganzhou, China, and Ganzhou Academy of Financial Research (GAFR), Ganzhou, China.

Author contributions

Ebenezer Fiifi Emire Atta Mills, PhD conceived the study and was responsible for the design of the manuscript. Ebenezer Fiifi Emire Atta Mills, PhD, Kailin Zeng, PhD, and Mavis Agyapomah Baafi were responsible for data collection and analysis. Kailin Zeng, PhD and Ebenezer Fiifi Emire Atta Mills, PhD were responsible for interpretation of results. Ebenezer Fiifi Emire Atta Mills, PhD and Mavis Agyapomah Baafi wrote the first draft of the manuscript. Kailin Zeng, PhD and Ebenezer Fiifi Emire Atta Mills, PhD were responsible for funding acquisition.

Disclosure statement

The authors declare no conflict of interest.

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