Print ISSN: 2288-4637 / Online ISSN 2288-4645
doi:10.13106/jafeb.2022.vol9.no10.0015

Is Economic Globalization Destructive to Air Quality? Empirical Evidence from China*

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Received: September 15, 2022 Revised: November 26, 2022 Accepted: December 05, 2022

Abstract

Recently, as carbon dioxide (CO_2) emissions have increased overall and contributed to air pollution, and awareness of environmental degradation has grown. This study examines the impacts and causalities of economic globalization, economic growth, energy consumption, and capital formation on CO_2 emissions in China over the period 1971–2014. The vector error correction model (VECM) and Granger causality test on time-series data are employed to observe the interactions between CO_2 emission, economic globalization, and various economic factors, including economic growth, energy consumption, and capital formation, since China's early stage of globalization. The empirical results indicate the existence of bidirectional causalities from economic growth, gross capital formation, economic globalization, and CO_2 emission to energy consumption, and bidirectional casualty from energy consumption to CO_2 emission relationships in the short run. The findings of this study suggest that indirect bidirectional causalities from economic growth, economic globalization, and capital formation to CO_2 emission through energy consumption are observed. Moreover, economic globalization accelerates CO_2 emission in the short run but decreases it in the long run. To reduce CO_2 emissions, and to ensure sustainable economic growth and economic globalization progress, some crucial energy-saving and energy-efficiency policies, regulatory rules, and laws are recommended.

Keywords: Chinese Economy, CO_2 Emission, Economic Globalization, VECM, Granger Causality

JEL Classification Code: C32, Q43, Q56, O44

1. Introduction

Since the industrial revolution, the production volume has improved due to productivity advances. This increase in the production volume has also led to a rise in the international trade volume. International trade promotes globalization that unifies markets and economies. In this aspect, the "concept of the globe as a single place" that the 1990s and 2000s gave rise to is still a phenomenon today. By removing the knowledge and savings limits and using the historical lessons of other globalized economies, this notion has had a tremendously stimulating effect on economic growth (Crafts, 2004). However, there are also adverse effects of a globalized world. One of these effects is that globalization significantly impacts the environment by enhancing economic growth through rising energy consumption and capital accumulation (Leal & Marques, 2021; Leal, Marques & Shahbaz et al., 2017; Rahman, 2020). In this case, economic growth with increasing production volumes requires more and more energy resources. Consuming relatively more energy resources is resulted in environmental degradation and deteriorating air quality, in a way carbon dioxide (CO_2) pollute the air. Reversely, Grossman and Krueger (1991), as a pioneer study, mentioned an inverted-U-shaped relationship between economic growth and some pollution. Economic growth has detrimental impacts on environmental degradation till the specific threshold value of income. When the income level reaches the threshold value, environmental degradation begins to decrease. As a consequence of negative effect of environmental degradation, the quality of

***Acknowledgements:**
This study is supported by the Ministry of National Education of the Republic of Turkey (Türkiye).

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life (welfare) can be affected by environmental conditions and the sustainable growth process.

China has been one of the most challenging countries in terms of comparing the impact of globalization on CO_2 emissions. According to World Bank-World Development Indicators (WB-WDI), China is now the second-largest economy after the United States and Japan. One of the causes underlying this situation can be China's membership of the World Trade Organization (WTO) in 2001 transformed China into the "World's factory" (Li, 2016). As the World's factory, China took over the place of the United States as the largest CO_2 the emitter in 2005, as shown in Figure 1.

According to BP's statistical evaluation of global energy, China tops the list of countries with the highest CO_2 emissions in 2018 and is responsible for more than 25% of all carbon dioxide emissions globally. Increased production volumes, which need more energy and appear to have led to environmental degradation, may cause the high rate of carbon emissions. But despite China's high ranking in terms of CO_2 emissions, it ranks lower in terms of economic globalization, coming in at 151^{st} in 2019 (Gygli et al., 2019). In terms of the Heckscher-Ohlin model, it is well known that the regions/countries export goods using abundant input factors (Leamer, 1995). Therefore, economies with greater levels of integration typically have fewer trade barriers that, if ignored, could result in environmental harm. On the other hand, the firms desire to escape higher costs caused by environmental regulations and energy prices, known as Pollution Heaven Hypothesis in the environmental literature, to increase their competitiveness (OECD, 2017). This migration of production, encouraged by globalization, may lead to an increase in environmental degradation by increasing the volume of production to developing countries, which are relatively lower costs from environmental regulations.

To deal with increasing crucial environmental degradation, China joined the Paris Climate Summit in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC) where China declared to reduce CO_2 emission by increasing non-fossil fuel consumption and forest stock up to 2030 (Gao, 2016). Despite this declaration, scenarios containing future predictions of CO_2 emission seemed grim and even had an upward trend. Several scholars have made predictions about the trends in CO_2 emissions for China in their studies. For instance, the estimations of Sun et al. (2022) point out that most Chinese provinces will reach a peak in carbon emissions before 2030 and achieve carbon naturality before 2060. Likewise, the predictions of Yu et al. (2018) demonstrate that the burgeoning trend of CO_2 the emission has its origin in the aging population and the industry structure (tertiary sector) as the main driver, and GDP per capita and technology seem to be less critical, and they also forecast a ridge regression increase in CO_2 by 2030. Other researchers, like Xu et al. (2019), who predicted CO2 emissions peaks, present three scenarios: low, medium, and high growth rates. In terms of these three scenarios, the findings illustrate that China is expected to reach the peak point of CO_2 emissions about after a decade. Therefore,

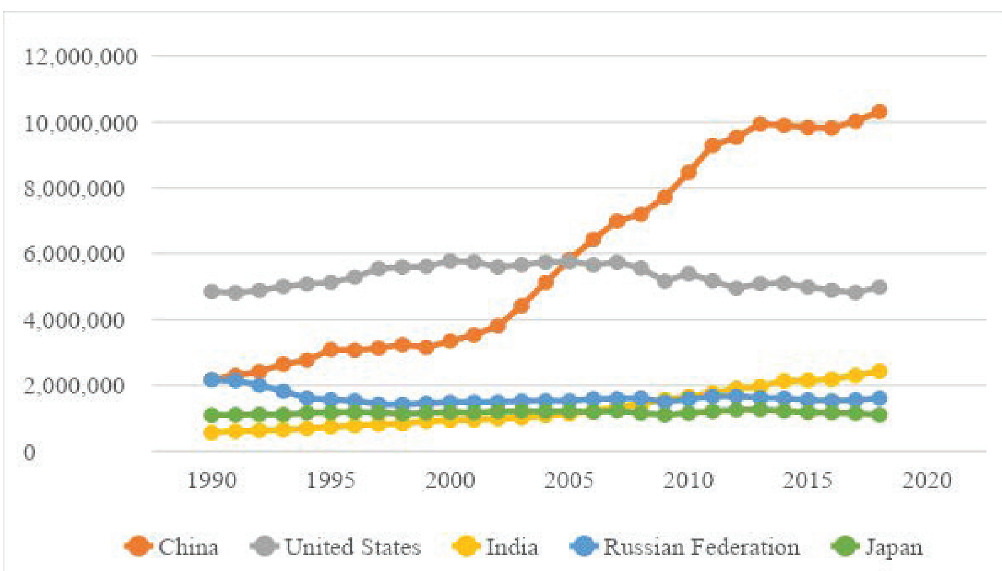

Figure 1: National Carbon Emission from 1990 to 2018 (Thousand Metric Tons)
Source: World Bank – World Development Indicators.

the rising CO_2 emissions due to economic factors tend to continue being a crucial problem in China in the near future.

It is crucial to find out what economic factors have impacts on air pollution in a developing nation like China. This aspect of China's economic globalization requires analysis to determine whether air pollution is a result of its increasing impact on production volume and, consequently, energy consumption. The answer to this query is significant since these findings can facilitate policymakers in neutralizing CO_2 emissions. To investigate this question, this study contributes to the existing literature by observing the causality and impacts among CO_2 emission, economic globalization, economic growth, energy consumption, and gross capital formation for the long and short run in China, covering the period 1971-2014. This study employs the cointegration test, VECM, the Granger causality test based on VECM, impulse-response function, and variance decomposition to analyze the impact and causalities between selected variables. The main results show the existence of bidirectional causalities from economic growth, gross capital formation, economic globalization, and CO_2 emission to energy consumption, and bidirectional casualty from energy consumption to CO_2 emission. The positive effects of energy consumption, economic growth, and gross capital formation on the CO_2 emission has also been observed through the research model of this study.

The structure of this study is as follows: the second section provides a concise and, more importantly, an empirical evaluation of the available literature. Based on the gaps in the literature, the model, the dataset, and the methodology are explained in the third part. The fourth part includes the empirical findings and discussion. The last part summarizes this study, recommends several policies, explains the limitations of this study, and proposes future research directions.

2. Literature Review

Even though there are several studies investigating the impact of economic factors on CO_2 emissions, only a limited number of studies explore the causality impact of economic globalization on CO_2 emission. Thus, the existing studies have been compiled into three main sections. The first section describes the linkages between globalization and environmental degradation, whereas the second section focuses on the relationship between energy consumption, economic growth, and ecological degradation. The third section demonstrates the relationship between economic growth and environmental degradation.

2.1. Association Between Globalization and Environmental Degradations

Scholars have studied limited empirical investigations that include different conclusions for the linkages between globalization and environmental degradation. Some of them have concluded that the positive impact of economic globalization on CO_2 emissions such as the study of Kalaycı and Hayaloğlu (2019) that focused on the NAFTA (Mexico, Canada, and the United States) countries between 1990 and 2015 employed panel-data analysis. Similarly, Khan et al. (2019), investigated Pakistan over the period from 1971 to 2016 by implementing dynamic ARDL and also found a positive effect of globalization on CO_2 emission. Shahbaz et al. (2018) studied the impacts of globalization on CO_2 emissions in Japan over the period 1970 to 2014, applied an asymmetric threshold version of the ARDL (NARDL) and found that negative and positive shock of globalization has a positive effect on CO_2 emission. Likewise, with a different methodology that is semi-parametric panel fixed effects model, Liu et al. (2020) explored the linkages between globalization and the CO_2 emission for the G7 countries between 1970 and 2015, and resulted in the existence of an inverted U-shaped relationship between economic globalization and CO_2 emissions. Ulucak et al. (2020) additionally found globalization contributes to CO_2 emissions in BRICS (Brazil, Russia, India, China, and South Africa) economies from 1990 to 2015. Furthermore, Yurtkuran (2021) demonstrated how globalization's positive effects on CO2 emissions demonstrate the scale effect's reality and how it was applied to Turkey between 1970 and 2017.

Besides the positive impacts of globalization on CO_2 emission, some studies conducted on the negative effect of globalization on CO_2 emissions; for example, the study of You and Lv (2018) for 83 countries between 1985 and 2013 employed the spatial panel method and found globalization decreased environmental degradation measured by CO_2 emissions. For 28 OECD countries over the period 1971–2016, Yang et al. (2021) also found a similar result in the long run by applying fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS). Similarly, Mehmood (2021) obtained the negative effect of economic and social globalization on CO_2 emission in the short and long run for Singapore between 1970 and 2014, applied the ARDL model. Khan et al. (2019) searched the environmental Kuznets curve (EKC) or China between 1970 and 2012 by implementing ARDL and VECM, founded reducing the effect of globalization on CO_2 emission.

On the other hand, Mehmood and Tariq (2020) investigated the linkages between globalization and CO_2 emissions for South Asian countries include Pakistan, India, Bangladesh, Sri Lanka, Afghanistan, Bhutan, and Nepal between 1972 and 2013. The ARDL and UECM findings demonstrate that globalization leads to higher CO_2 emissions. Globalization reduces CO_2 emissions in Pakistan and Bhutan for the stages of globalization that come after the threshold level because there is evidence for inverted U-shape relationships between globalization and CO_2 emissions.

2.2. Association Between Energy Consumption and Environmental Degradations

Several significant studies are available about the linkages between energy consumption and CO_2 emissions. In this aspect, Ahmad et al. (2019) examined the positive impacts of energy consumption growth on CO_2 emissions for 30 Chinese provinces over the period 2000–2016. Similarly, Jian et al. (2019), Khan et al. (2020), Muhammad (2019), Muhammad and Khan (2019), Nawaz et al. (2021), Ozcan et al. (2020), Ssali et al. (2019) and Usman et al. (2019) confirmed the positive effect of energy consumption on CO_2 emissions. Nonetheless, Appiah (2018) found unidirectional causality between energy use and CO_2 emission in Ghana covering the time period 1960–2015.

2.3. Association Between Economic Growth and Environmental Degradations

Scholars have carried out numerous empirical studies that have different conclusions about economic growth and CO_2 emission. For instance, Mikayilov et al. (2018) found a positive impact of economic growth on CO_2 emission in Azerbaijan between 1992 and 2013 by implementing ARDLBT, DOLS, FMOLS, and CCR methods. Likewise, Ahmad et al. (2019), Bhat (2018), Chen et al. (2019), Hanif et al. (2019), Khan et al. (2019), Muhammad (2019), and Naz et al. (2019) also investigated the positive effect of economic growth on CO_2 emissions. Park et al. (2018), interestingly, found a negative effect of economic growth on CO_2 emission in selected European Countries over the period 2001–2014, employed pooled mean group (PMG) estimator. Similarly, Acheampong (2018) observed the harmful effects of economic growth on CO_2 emission in the global level and Caribbean-Latin America covering the period 1990–2014. On the other hand, Hanif (2018) proved the existence of inverted U-shape linkages between economic growth and CO_2 emissions, applied a system generalized method of moment (GMM) in 34 emerging countries between 1995 and 2015. Hamid et al. (2022), differently explored the increasing impact of a positive shock of economic growth on CO_2 emissions, and the diminishing effect of a negative surprise of economic growth on CO_2 emissions in Oman over the period 1980–2019.

3. Data and Methodology

3.1. Data

This empirical study employed annual data of China covering the period 1971–2014. As a dependent variable, CO_2 emission data is extracted from World Bank-World Development Indicators (WB-WDI) to measure environmental degradation. To calculate the effects of the total energy consumption on other variables, energy use data is compiled from WB-WDI. In order to observe the impact of economic growth effect on CO_2 emission, GDP per capita is used from WB-WDI. The economic globalization index is used to measure the level of openness of China from the World KOF Swiss Economic Institute. To observe the capital accumulation, gross capital formation is employed from WB-WDI. All the variables, their notations, definitions, and sources are indicated in Table 1.

3.2. Model Specification

The research model of this study focuses on the related literature with some modifications. The main variable is CO_2 that is an indicator of environmental degradation.

Table 1: Notations and Sources of Variables

Variable/Notation	Definition	Source
CO_2*	CO_2 emissions (kg per 2015 US$ of GDP)	WDI-WB
EU*	Energy use (kg of oil equivalent per capita)	WDI-WB
GDP*	GDP per capita (current US$)	WDI-WB
G*	Economic Globalization Index	KOF Swiss Economic Institute
K	Gross capital formation (% of GDP)	WDI-WB

Note: *Denotes the logarithm form. WDI-WB indicates World Development Indicator-World Bank.

EU and K observe the production input structure. GDP measures the level of economic development. G measures the spillover effect of technology, know-how, and production and consumption relationship. Thus, EU, GDP, G, and K are added as independent variables in the econometric model. The econometric research model is indicated below;

$$CO_2 = f(\text{EU, GDP, G, K}) \tag{1}$$

An extended and generalized research model is;

$$CO_2 = \alpha_0 + \alpha_1 \text{EU} + \alpha_2 \text{GDP} + \alpha_3 \text{G} + \alpha_4 \text{K} + \varepsilon_t \tag{2}$$

In the second (2) equation α_0 indicates the intercept of the model, $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and α_5 represents the elasticity coefficients of, respectively, EU, GDP, G, and K.

3.3. Unit Root, Cointegration, and Causality Tests

Regarding handling stationary, this study implements the Phillip-Perron unit root test (Phillips & Perron, 1988). Stationary variables can give the right cointegration relationship. After determining the stationarity of the selected variables, the Johansen cointegration test is implanted to observe cointegration for time series data. If the critical value exceeds 5%, the null hypothesis (r = 0) accepts no cointegration connection between variables. The VECM model is developed to observe short- and long-term equilibriums with cointegration of the variables based on this relationship. A long-run equilibrium relationship exists to implement VECM that assesses short-run interactions, effects, and causalities across the time series, considering the selected variables are cointegrated in this study. Assuming the variables in this study are cointegrated, the following are the VECM equations:

$$\begin{aligned} \text{dCO}_{2t} &= c_1 + \sum_{i=1}^{n} \alpha_{1i} \text{dCO}_{2t-i} + \sum_{i=1}^{n} \beta_{1j} \text{dEU}_{t-j} \\ &+ \sum_{i=1}^{n} e_{1l} \text{dGDP}_{t-l} + \sum_{i=1}^{n} \gamma_{1k} \text{dG}_{t-k} \\ &+ \sum_{i=1}^{n} x_{1m} \text{dK}_{t-m} + \varnothing_1 \text{ETC}_{t-1} + \varepsilon_{1t} \end{aligned} \tag{3}$$

$$\begin{aligned} \text{dEU}_{t} &= c_2 + \sum_{i=1}^{n} \alpha_{2i} \text{dEU}_{t-i} + \sum_{i=1}^{n} \beta_{2j} \text{dCO}_{2t-j} \\ &+ \sum_{i=1}^{n} e_{2l} \text{dGDP}_{t-l} + \sum_{i=1}^{n} \gamma_{2k} \text{dG}_{t-k} \\ &+ \sum_{i=1}^{n} x_{2m} \text{dK}_{t-m} + \varnothing_2 \text{ETC}_{t-1} + \varepsilon_{2t} \end{aligned} \tag{4}$$

$$\begin{aligned} \text{dGDP}_{t} &= c_3 + \sum_{i=1}^{n} \alpha_{3i} \text{dGDP}_{t-i} + \sum_{i=1}^{n} \beta_{3j} \text{dCO}_{2t-j} \\ &+ \sum_{i=1}^{n} e_{3l} \text{dEU}_{t-l} + \sum_{i=1}^{n} \gamma_{3k} \text{dG}_{t-k} \\ &+ \sum_{i=1}^{n} x_{3m} \text{dK}_{t-m} + \varnothing_3 \text{ETC}_{t-1} + \varepsilon_{3t} \end{aligned} \tag{5}$$

$$\begin{aligned} \text{dG}_{t} &= c_4 + \sum_{i=1}^{n} \alpha_{4i} \text{dG}_{t-i} + \sum_{i=1}^{n} \beta_{4j} \text{dCO}_{2t-j} \\ &+ \sum_{i=1}^{n} e_{4l} \text{dEU}_{t-l} + \sum_{i=1}^{n} \gamma_{4k} \text{dGDP}_{t-k} \\ &+ \sum_{i=1}^{n} x_{4m} \text{dK}_{t-m} + \varnothing_4 \text{ETC}_{t-1} + \varepsilon_{4t} \end{aligned} \tag{6}$$

$$\begin{aligned} \text{dK}_{t} &= c_5 + \sum_{i=1}^{n} \alpha_{5i} \text{dK}_{t-i} + \sum_{i=1}^{n} \beta_{5j} \text{dCO}_{2t-j} \\ &+ \sum_{i=1}^{n} e_{5l} \text{dEU}_{t-l} + \sum_{i=1}^{n} \gamma_{5k} \text{dGDP}_{t-k} \\ &+ \sum_{i=1}^{n} x_{5m} \text{dG}_{t-m} + \varnothing_5 \text{ETC}_{t-1} + \varepsilon_{5t} \end{aligned} \tag{7}$$

where d denotes the first differentiations, and $c, \alpha, \beta, e, \gamma$, and x demonstrate coefficients of the polynomials. Moreover, n is the optimal lag; ETC_{t-1} illustrates lagged error correction terms. $\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, \varepsilon_{4t}, \varepsilon_{5t}$ and ε_{6t} shows disturbance terms. Consider equation 3 as an example; it describes the causality relationship from EU, GDP, G, K to CO_2. When the null hypothesis $(H_0 : \beta_{1j} = e_{1l} = \gamma_{1k} = x_{1m} = 0)$ is rejected in equation 3, short-run Granger causality relationship from EU, GDP, G, K to CO_2 is existed. On the other hand, $\varnothing_1$ represents error correction term that determines the change speed toward CO_2 equilibrium. Long-term Granger causality is demonstrated from right to left if the null hypothesis (H_0: $\varnothing_1 = 0$) is rejected. The same rationality is also valid for other equations (4, 5, 6, and 7).

3.4. Impulse-Response Function (IRF) and Variance Decomposition

This study employs the IRF and variance decomposition method. IRF explains when a positive shock on a variable is implemented and how other variables react to this positive shock. IRF has ten years period to examine the effect of the positive shock on variables in this study. On the other hand, variance decomposition decomposes the mean square error and examines the influence of endogenous factors on each variable. The variance decomposition technique compares the contributions of different variables to each other.

4. Empirical Findings and Discussion

The descriptive statistical results reported in Table 2 give information about the five variables in the model and show a brief and concise overview of the data in this study of forty-four observations/years. In general, the five variables seem relatively suitable for the model, as no stark outliers have been discovered. The data's skewness and kurtosis values show how the variables' distribution is shaped. All variables have a kurtosis (sharpness) value of less than three. Inferred from the fact that all variables follow the normal distribution is that the concentration is lower than typical. The variables' distribution can be considered to be approximately symmetrical.

Before the cointegration test, the stationary of the variablesmust be tested. Otherwise, spurious regression can occur. In this aspect, Table 3 presents the result of the Phillips-Peron unit root test. CO_2, EU, GDP, G, and K are stationary at the first difference. Thus, all variables are I(1). These results prove the suitability to implement the Johansen cointegration test and VECM. After the determination of the stationary of the variables, the optimal lag has to be selected. Therefore, in terms of the democratic multiplicity of the criteria that includes sequential modified LR test (LR),

Table 2: Descriptive Statistics

	CO_2	EU	GDP	*G*	*K*
Mean	0.675117	6.778103	6.402282	3.391105	37.78886
Median	0.613970	6.656071	5.918585	3.447675	37.26478
Maximum	1.389442	7.707222	8.940644	3.948933	46.66012
Minimum	–0.043407	6.141894	4.776217	2.879198	31.24832
Std. Dev.	0.486264	0.465760	1.248666	0.384078	4.470177
Skewness	0.118523	0.700680	0.633532	–0.101467	0.629600
Kurtosis	1.419985	2.342855	2.152470	1.468747	2.363814
Jarque-Bera	4.679834	4.392028	4.260222	4.374180	3.648918
Probability	0.096336	0.111246	0.118824	0.112243	0.161305
Sum	29.70516	298.2365	281.7004	149.2086	1662.710
Sum Sq. Dev.	10.16747	9.328100	67.04412	6.343198	859.2467
Observations	44	44	44	44	44

Table 3: Results of Unit Root Test

	I(0)			I(1)		
	With Constant	**With Constant & Trend**	**Without Constant & Trend**	**With Constant**	**With Constant & Trend**	**Without Constant & Trend**
CO_2	0.0341 (0.9565)	–2.1512 (0.5036)	–2.2183 (0.0271)**	–4.144 (0.0023)***	–4.1078 (0.0124)**	–3.0107 (0.0035)***
EU	1.2976 (0.9983)	–0.9053 (0.9461)	4.6555 (1.0000)	–3.5677 (0.0108)**	–3.7111 (0.0325)**	–2.2811 (0.0234)**
GDP	2.6896 (1.0000)	–0.5259 (0.9784)	7.5705 (1.0000)	–5.1561 (0.0001)***	–6.1284 (0.0000)***	–2.8496 (0.0054)***
G	–0.6840 (0.8400)	–1.4500 (0.8312)	2.9169 (0.9988)	–5.0978 (0.0001)***	–5.0753 (0.0009)***	–4.1944 (0.0001)***
K	–0.9543 (0.7609)	–2.6074 (0.2792)	1.3226 (0.9509)	–5.6142 (0.0000)***	–5.4661 (0.0003)***	–5.2927 (0.0000)***

Note: ** and *** represent the significance value of %5 and %1.

final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SC), Hannan-Quinn information (HQ), optimal lag is selected two as shown in Table 4.

The results of the Johansen cointegration test in Table 5, the null hypothesis is rejected at a 5% significance level in terms of trace and maximum Eigen Value statistics. As a result, two methods (Trace and Maximum Eigenvalue statistics) show one cointegration relationship among variables. Long-run cointegration demonstrates the viability of the VECM system.

Table 6 demonstrates the results of the VECM. In terms of VECM, five models have sufficient explanatory power, with *R*-squared values of roughly 39, 68, 50, 22, and 24 percent, respectively. This suggests that independent variables can explain these percentages of dependent variables that are relatively high. On the other hand, to test the reliability and stability of the model, some diagnostic tests such as autocorrelation, normal distribution, and heteroskedasticity of residuals are performed. The results of diagnostic tests confirm that residuals are uncorrelated, normally distribute, and homoscedastic in terms of the diagnostic tests.

The results of the Granger tests based on VECM that contained short-run and long-run correlations are provided in Table 7 and Figure 2, illustrating the bilateral causalities after performing the Granger causality test following VECM to determine the causality linkages among the selected variables. In terms of the short-run Granger causality test, the indirect bidirectional causalities from economic growth, economic globalization, and capital formation to CO_2 emission through energy consumption are observed that is in line with the study of Murshed et al. (2022) regards with the indirectness from economic globalization to carbon emission.

In terms of IRF, as seen in Figure 3, a positive shock on EU, GDP, and K has a positive impact on CO_2. A positive shock on G has a positive effect on CO_2 in the short-run (assumed 3 years), while a positive shock on G has a negative effect on CO_2 in the long run (assumed 10 years). On the contrary, Chuah et al.(2022) found a positive effect of globalization in the both short and long run. Furthermore, a positive shock on CO_2, GDP and K have a positive impact on the EU, while a positive shock on G has a negative effect on the EU in the long run. The IRF’s findings are consistent with research by Vu and Huang (2020) and Nguyen et al. (2021) regarding the beneficial impact of economic growth (GDP) on CO2 emissions. On the other hand, the result of the positive impact of energy usage on CO_2 emission is in-line with the study of Jian et al. (2019). There is also a similarity in the results in terms of the positive relationship between economic globalization and CO_2 emissions of this study compared with the study of Kalaycı and Hayaloğlu (2019).

The variance decomposition method indicates the variance decomposition analysis results, which explains the

Table 4: Lag Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	–31.69477	NA	4.12E–06	1.789989	1.998961	1.866085
1	227.6355	442.7591	4.52E–11	–9.640758	**–8.386925***	**–9.184181***
2	255.3252	**40.52143***	**4.20e–11***	**–9.771960***	–7.473266	–8.9349
3	276.0547	25.2799	6.01E–11	–9.563644	–6.220089	–8.34611

Notes: **LR:** sequential modified LR test statistic (each test at 5% level), **FPE:** Final prediction error, **AIC:** Akaike information criterion, **SC:** Schwarz information criterion, **HQ:** Hannan-Quinn information criterion.

Table 5: Johansen Cointegration Test

	Trace Statistic		**Maximum Eigen Value Statistic**	
	Statistic	**Critical Value**	**Statistic**	**Critical Value**
None *	**79.15524***	69.81889	**34.36315***	33.87687
At most 1	44.79209	47.85613	19.74919	27.58434
At most 2	25.04289	29.79707	14.58386	21.13162
At most 3	10.45903	15.49471	10.45802	14.2646
At most 4	0.00101	3.841465	0.00101	3.841465

Note: *(5%) is represented the significance values of statistics.

Table 6: Vector Error Correction Results

Error Correction	**D(CO_2)**	**D(EU)**	**D(GDP)**	**D(G)**	**D(K)**
ECT1	0.063929 –0.04059 [1.57497]	–0.0798 –0.02465 [–3.23735]	–0.1158 –0.07429 [–1.55879]	–0.04394 –0.04162 [–1.05573]	–2.68692 –2.00689 [–1.33885]
D(CO_2 (–1))	0.013288 –0.25724 [0.05165]	0.761116 –0.15621 [4.87233]	–0.02401 –0.47082 [–0.05100]	0.036913 –0.26377 [0.13994]	8.9132 –12.7187 [0.70079]
D(CO_2 (–2))	–0.06901 –0.2567 [–0.26881]	0.261273 –0.15588 [1.67609]	–0.53187 –0.46983 [–1.13206]	0.233329 –0.26322 [0.88645]	8.646948 –12.6919 [0.68130]
D(EU(–1))	0.795158 –0.38468 [2.06707]	–0.28845 –0.2336 [–1.23480]	0.45496 –0.70406 [0.64620]	–0.41389 –0.39444 [–1.04930]	–7.99865 –19.0194 [–0.42055]
D(EU(–2))	–0.16357 –0.31776 [–0.51476]	–0.57049 –0.19296 [–2.95654]	0.821343 –0.58158 [1.41227]	–0.41903 –0.32583 [–1.28607]	–20.0169 –15.7107 [–1.27410]
D(GDP(–1))	–0.06056 –0.08797 [–0.68837]	0.061912 –0.05342 [1.15897]	–0.05955 –0.16101 [–0.36985]	–0.03581 –0.0902 [–0.39700]	0.114637 –4.3494 [0.02636]
D(GDP(–2))	–0.00245 –0.0821 [–0.02979]	0.097468 –0.04985 [1.95510]	0.108677 –0.15026 [0.72328]	0.02987 –0.08418 [0.35483]	–0.64164 –4.059 [–0.15808]
D(G(–1))	–0.10711 –0.19254 [–0.55630]	–0.24507 –0.11692 [–2.09596]	–0.22469 –0.3524 [–0.63760]	0.080864 –0.19743 [0.40958]	–16.7847 –9.51978 [–1.76314]
D(G(–2))	0.089974 –0.1888 [0.47657]	0.121907 –0.11465 [1.06333]	0.163475 –0.34554 [0.47310]	–0.03839 –0.19359 [–0.19833]	3.152717 –9.33445 [0.33775]
D(K(–1))	–0.00119 –0.00386 [–0.30887]	0.003596 –0.00235 [1.53312]	0.002501 –0.00707 [0.35368]	0.00562 –0.00396 [1.41871]	0.354381 –0.191 [1.85542]
D(K(–2))	0.001854 –0.00381 [0.48699]	0.008038 –0.00231 [3.47680]	0.003405 –0.00697 [0.48871]	0.003171 –0.0039 [0.81230]	–0.15071 –0.18823 [–0.80069]
C	–0.05028 –0.03187 [–1.57780]	0.083745 –0.01935 [4.32756]	0.025567 –0.05833 [0.43835]	0.058845 –0.03268 [1.80085]	2.16176 –1.57559 [1.37203]
R–squared	0.389806	0.678255	0.502757	0.217609	0.253525

Note: Standard errors in ( ) & *t*-statistics in [ ].

Table 7: Long and Short-Run Causality

Dependent Variables	Short-Run Causality						Long-Run Causality	Results
	D(CO_2)	**D(EU)**	**D(GDP)**	**D(G)**	**D(K)**	**Results**	**ECT1**	
D(CO_2)	–	**6.368683 0.0414****	0.473952 0.7890	0.494748 0.7808	0.324363 0.8503	EU > CO_2	0.063929 [1.57497]	–
D(EU)	**23.808080 0.0000*****	–	**5.037748 0.0806***	**5.179497 0.0750***	**14.749580 0.0006*****	CO_2, GDP, G, K > EU	**–0.079797 [–3.23735]*****	CO_2, GDP, G, K > EU
D(GDP)	1.465514 0.4806	2.003898 0.3672	–	0.582895 0.7472	0.373932 0.8295	–	–0.115804 [–1.55879]	–
D(G)	0.837345 0.6579	2.001764 0.3676	0.291983 0.8642	–	2.739443 0.2542	–	–0.043941 [–1.05573]	–
D(K)	0.685764 0.7097	1.631313 0.0259	0.025948 0.9871	3.143711 0.2077	–	–	–2.68692 [–1.33885]	–

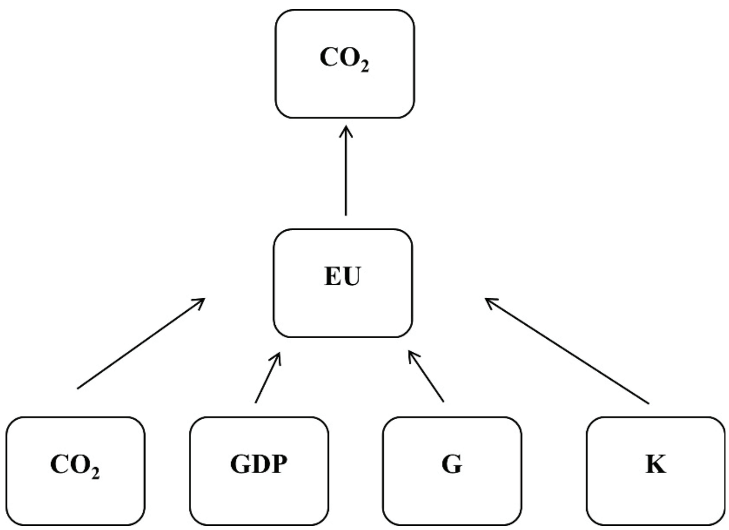

Figure 2: Short-Run Causality Directions

contribution level of variables. The contribution rate of EU, GDP, and G on CO_2 are respectively 2.1%, 7.5%, and 3.1% in the tenth period. Moreover, the contribution rate of CO_2 and GDP in the EU is respectively 82.5% and 2.69% in the tenth period. On the other hand, the contribution rate of CO_2, EU, G, and K on GDP are 54.6%, 14.7%, 1.4%, and 8.8%, respectively. GDP has explanatory power on G with 23.7% which is relatively high. GDP and G have explanatory power on K with 9.12% and 5.3%.

5. Conclusions and Policy Recommendations

The objective of this paper is to explore the causalities and impacts of CO_2 emission, energy consumption, economic growth, economic globalization, and gross capital formation in China between 1971 and 2014. Phillips-Perron unit root test, Johansen cointegration test, VECM, the Granger causality test based on VECM, impulse-response function, and variance decomposition method are applied in this paper.

Figure 3: Results of the IRF Analysis

The empirical result mainly demonstrates a long-run cointegration relationship among the selected variables for this study. In terms of the Granger causality test, bidirectional causality from energy consumption to CO_2 emissions, and bidirectional causalities from CO_2 emissions, economic growth, economic globalization, and gross capital formation to energy consumption are founded in the short run. There are also linkages from CO_2 emissions, economic growth, economic globalization, and gross capital formation to energy consumption. Thus, the findings indicate the indirect bidirectional causalities from economic growth, economic globalization, and capital formation to CO_2 emission through energy consumption. Moreover, energy consumption, economic growth, and gross capital formation have positive effects on environmental degradation, measured by CO_2 emission.

This study has crucial results and policy recommendations through the aim of the research model. Regarding the empirical results of this paper, the policymakers in China are recommended to subsidize energy-saving/energy-efficient production structures. In this way, China has the opportunity to improve air quality with the decrease in CO_2 emission to serve better living conditions. Furthermore, policymakers should arrange the regulations and laws, including limitations on the emitting carbon emissions, or confront the agents directing relatively higher taxes for the production process that has carbon emissions above the limitations, in the direction of cleaner and sustainable globalization and economic growth. With the implementation of this policy, economic growth, as well as economic globalization, can be purified from the degradation effect on air quality. Promoting and subsidizing environmental-friendly projects and products with energy-saving technologies is also advocated to be the aim direction of China. End-of-pipe technologies, which include shielding/protecting materials such as filters, scrubbers and cyclones just before the carbon emission is released into the air, could be another solution to reduce carbon emissions in China.In conclusion, energy consumption, economic growth, and economic globalization have essential impacts on carbon dioxide emissions in China. Presupposed the harmful effects of economic globalization on air quality, it is advocated that policymakers in China have to arrange their globalization policy with the awareness of its negative environmental impact, especially in the short run. Furthermore, this paper has some limitations regarding the suitability of the data period that is limited from 1970 and 2014 and is only annual data covering this period. Hence, the number of observations is limited. Moreover, the selected variables for the research model of this study have no province and/or city-level data. Future research directions are proposed to include the impacts of sub-factors of economic globalization on environmental degradation. Moreover, the post covid-19 impacts of economic globalization on environmental degradation is also proposed to analyze.

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