

## Impact of globalization on CO<sub>2</sub> emissions in Vietnam: An autoregressive distributed lag approach

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### ABSTRACT

This study aims at investigating the impact of globalization on CO<sub>2</sub> emission in Vietnam. Empirical analysis is performed by employing autoregressed distributed lag approach on time series data for the period of 1990 to 2016. The paper tested the stationary, cointegration of time series data and utilized autoregressed distributed lag modeling technique to determine the short run and long run relationship among CO<sub>2</sub> emission, globalization, foreign direct investment, exports, coal consumption per capita and fossil fuels electricity generation. The results show that globalization increases CO<sub>2</sub> emission in Vietnam and thus globalization is not beneficial for the long-term environmental health. Exports lowers CO<sub>2</sub> emissions in both short run and long run whereas coal consumption per capita and fossil fuels electricity generation raise CO<sub>2</sub> emissions. The study further shows that foreign direct investment did not affect CO<sub>2</sub> emissions directly in short run as well as in long run.

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## 1. Introduction

Globalization reflects an ongoing process of greater interdependence among countries and their citizens (Fischer, 2003). It has spurred a growing degree of interdependence among economies and societies through transboundary flows of information, ideas, technologies, goods, services, capital, and people. As a multidimensional concept, globalization expresses the extension process of economic, political and social activities across national borders. Globalization process is one of the main reasons behind global environmental changes. The globalization process may affect the environment in three ways, i.e., income effect, technique effect, and composition effect. Globalization encourages economic activity through trade and production of the impulse of goods, which damages the environment thereby inducing carbon dioxide emissions globally. This phenomenon is known as income effect. Through globalization, countries use energy-efficient technologies by accessing international markets. These technologies can be used to increase the domestic production with the minimal energy usage, which reduces the carbon dioxide emission level and improve environmental quality. This phenomenon is called technique effect. The composition effect happens when the structure of production and capital-labor ratio changes due to the globalization, which ultimately affects the environmental quality. Composition effect has a direct link with economic activities and carbon emissions due to agricultural, industrial, and service sector pollution intensity. As the economy moves from agriculture to the industrial sector, carbon dioxide emissions increases, and when it advances from the industrial sector

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to service sector, it begins to decline (Shahbaz et al., 2018). Hence, globalization may have a significant impact on carbon dioxide emissions (environment degradation).

Vietnam has followed the globalization trend since early 1990s. Globalization has helped developing countries such as Vietnam increase international trade growth and accelerate financial flows. It raised economic growth (Nguyen & Tran, 2018) and industrial development substantially (Nguyen, 2019), leading to a drastic shift of production activities to the country. The developing economies including Vietnam want to improve economic growth by increasing economic activities, trading, foreign and domestic investment, production level, and industrialization. The increased economic activities has led to increase in energy consumption. High consumption of energy in developing economies leads towards more carbon dioxide emissions. In Vietnam, carbon dioxide emissions has grown dramatically from 17.39 thousands of tonnes in 1990 to 187.1 thousands of tonnes in 2016 with rapid pace of globalization in the past nearly three decades. Globalization is a global process, and its effects will broaden and deepen over time. The impact globalization on environment has drawn much interest of reseachers and policy makers in recent times due to increased awareness of greenhouse emissions and its impact on air quality. An interesting trend observed in the impact of globalization on environmental quality, in particular the carbon dioxide emissions, has attracted studies on the subjects of globalization. However, the results of these studies show that environmental consequences of globalization remain controversial. Moreover, the relationship between globalization and environmental in Vietnam has not been deeply evaluated by previous researchers and there is apparently a need to fill this research gap.

This paper aims to empirically examine the impact of globalization on environmental quality, measured by carbon dioxide emissions, in Vietnam spanning the period 1990-2016. Unlike previous empirical studies, which had employed various proxies for globalization such as foreign direct investment (FDI), openness, etc., this study uses the composite KOF globalization index that encompasses different dimensions of globalization and prevents excessive oversimplification of complexities involved in understanding the ongoing process of globalization. The current study is hoped to contribute to the existing literature of globalization by answering research question: How does globalization affect the CO<sub>2</sub> emissions in Vietnam? The findings of the study provide policy directions to policy makers to give effective environmental policy, and in addition serve as reference material to researchers interested in the current topic.

The rest of the paper is structured as follow: section 2 summarizes the related literature; section 3 briefly presents the estimation strategy; section 4 discusses the results; finally, the conclusion and policy suggestions are provided in section 5.

## **2. Literature review**

The relationship between globalization and environment is a heated and highly debated topic in the development literature. Theoretical studies report a contradictory discussion on the relationship between globalization and environmental quality. Some of the studies found positive the effect of globalization on environment, others argued that globalization has harmful effect on environment. Despite the conflicting theoretical views, many studies have been empirically examined the impact of the globalization on environment in developed countries as well as developing ones. The results of these studies have been some what divergent, so that globalization has been described as a two-edged sword that has brought benefits to some and misery to others.

Most of the empirical studies have placed their efforts on understanding the impacts of traditional and modern globalization indicators on environmental quality, measured by various environmental indicators such as CO<sub>2</sub> emissions, SO<sub>2</sub> emissions and NO<sub>2</sub> emissions in developed countries as well as developing ones (Machado, 2000; Antweiler et al., 2001; Christmann & Taylor, 2001; Shin, 2004; Managi, 2004, 2008; Chang, 2012; Shahbaz et al., 2012; Kanzilal & Ghosh, 2013; Shahbaz et al., 2013; Tiwari et al., 2013; Ling et al., 2015; Lee & Min, 2014; Shahbaz et al., 2015a, b).

Many of these studies have mainly used trade openness as a narrowly defined indicator of globalization with less attention paid to its other aspects, i.e., socio-economic and political globalization. Results of these studies show that trade openness can affect environmental quality in both positive and negative ways. Jena and Ulrike (2008) report that though the impact of trade liberalization is not unique across pollutants, it improves environmental quality by lowering CO<sub>2</sub> and NO<sub>2</sub> emissions for industrial cities in the Indian economy. Shin (2004) also reports that trade openness is not harmful to the domestic environment in Chinese cities by using survey data. Shahbaz et al. (2012) reveal that trade openness reduces CO<sub>2</sub> emissions in Pakistan. Shahbaz et al. (2013) also report that trade openness reduces CO<sub>2</sub> emissions in Indonesia. Similarly, Kanzilal and Ghosh (2013) find that trade openness reduces CO<sub>2</sub> emissions in India. Ling et al. (2015) report that trade openness improves environmental quality in Malaysia by lowering CO<sub>2</sub> emissions. On the contrary, Neumayer (2000) critically assesses three ways in which trade might harm the environment. First, trade liberalization might exacerbate existing levels of resource depletion and environmental pollution; second, open borders might allow companies to migrate to “pollution havens”, thus undermining high environmental standards in host countries; and third, the dispute settlement system of the World Trade Organization (WTO) might favor trade over environmental interests in case of conflict. It is shown that while trade liberalization can lead to an increase in environmental degradation, pollution havens are not a statistically significant phenomenon. Saboori et al. (2012) conclude that trade openness is not the major contributing factor to the environment in Malaysia. Tiwari et al. (2013) reinvestigate the dynamic causal relationship between trade openness and CO<sub>2</sub> emissions for India and find that trade openness significantly increases CO<sub>2</sub> emissions. However, while examining the environmental consequences of trade liberalization on the quality of the environment for 50 developed and developing countries over the data period of 1960–2000, Baek et al. (2009) find that trade liberalization improves environmental quality by lowering SO<sub>2</sub> emissions in developed economies, whereas it has a detrimental effect on the quality of environment in most developing economies. Managi (2004) explores the environmental consequences of trade liberalization by using panel data over the period of 1960–1999 for 63 developed and developing countries and finds that trade openness increases CO<sub>2</sub> emissions. Moreover, Grossman and Krueger (1991) argue that the environmental effects of international trade depend on policies implemented in domestic economies, irrespective of their size and development levels. The proponents of trade openness suggest that trade openness results in production efficiency of the trade-participating countries by allocating scarce resources among them. Trade openness lowers CO<sub>2</sub> emissions by using standard and cleaner technologies in production and consumption activities (Runge, 1994; Helpman, 1998). Antweiler et al. (2001) examine the effect of trade on environmental quality by introducing composition, scale and technological effects through decomposing a trade model. Their study concludes that trade openness is beneficial to the environment if the technological effect is greater than both the composition and scale effects. Copeland and Taylor (2003, 2004), through their pollution haven hypothesis that refers to the relocation of heavy industries from developed countries with stringent environmental policies to countries with lax environmental regulations, also support international trade as highly beneficial to environmental quality through the enforcement of strong environmental regulations. They document that free trade reduces CO<sub>2</sub> emissions in developed countries because it shifts the production of pollution-intensive goods from developed countries to developing nations. McCarney and Adamowicz (2006) also assert that trade openness improves the quality of the environment, depending on government policies. Managi et al. (2008) find that environmental quality is improved if the effect of environmental regulations is stronger than the capital-labour effect.

The second group of studies has attempted to investigate the impact of FDI on the environment in developing countries. The impact on environment could be direct through the shifting of dirty industries from the advanced countries to the developing countries and due the comparatively lower levels of pollution norms (Pollution Heaven Hypothesis). Empirical studies on impact of FDI on environment are still relatively sparse and has been rather mixed both in the developed and developing countries. For instance, He (2006) has explored the relationship between FDI and the environment in China and

found that an increase in FDI inflows results in deterioration of environmental quality. However, these studies implicitly assume a one-way causality from measures of environmental quality (SO<sub>2</sub> and CO<sub>2</sub> emissions) and adopt a structural model (i.e., reduced form equations) to estimate the impacts of FDI based on such causality. Baek et al. (2009), using cointegration analysis and a Vector Error Correction model (VECM), have examined the short and long run relationships among foreign direct investment (FDI), economic growth and the environment in China and India. The results show that a FDI inflow in both countries was found to have a detrimental effect on environmental quality in both the short-run and long-run. Also, they found that, in the short-run, there exists a unidirectional causality from FDI inflows to the environment in China and India a change in FDI inflows causes a change in environmental quality but the obverse does not hold.

Some new studies in the existing literature have survey the impact of globalization on CO<sub>2</sub> emissions by using the newly developed globalization index and time series and panel frameworks. Christmann and Taylor (2001) examine the linkage between globalization and the environment and confirm that globalization is not detrimental to environmental quality in China. They also claim that Chinese firms' international linkages largely contribute to environmental quality through the effective implementation of environmental regulations. They further argue that environmental quality is achieved because of the self-regulation of Chinese firms. Subsequently, Lee and Min (2014) examine the effect of globalization on CO<sub>2</sub> emissions for a larger annual panel data set of both developed and developing countries in a panel framework and find that globalization significantly reduces CO<sub>2</sub> emissions. Shahbaz et al. (2015b) also investigate the impact of globalization on CO<sub>2</sub> emissions for the Australian economy and find a role for globalization in lowering CO<sub>2</sub> emissions, highlighting that environmental quality in Australia is achieved in the presence of globalization. In contrast, Shahbaz et al. (2015a) investigate the impact of globalization on environmental quality for India and find a positive effect of globalization on CO<sub>2</sub> emissions, indicating that globalization weakens environmental quality in India. Shahbaz et al. (2017a) investigate the relationship between globalization and CO<sub>2</sub> emissions by using a panel of 25 developed countries in period of 1970–2014. The empirical results reveal that globalization increases carbon emissions, and thus the globalization-driven carbon emissions hypothesis is valid. Shahbaz et al. (2017b) examine the effects of globalization on CO<sub>2</sub> emissions in Japan by using annual data from 1970 to 2014 and an asymmetric threshold version of the ARDL model. They conclude that globalization significantly increases carbon emissions in Japan in the short run. Khan et al. (2019) employ modern econometric techniques such as Johansen co-integration, ARDL bound testing approach, and variance decomposition analysis to test the relationship between globalization and carbon dioxide emissions in case of Pakistan in the period of 1975–2014. Results show that there is a significant long-run relationship between carbon dioxide emissions and globalization. They find that a 1% increase in economic globalization, political globalization, and social globalization will increase carbon dioxide emissions by 0.38, 0.19, and 0.11%, respectively. Economic, political, and social globalization are contributing significantly to carbon dioxide emissions in Pakistan. Destek (2019) investigate the impact of different dimensions of globalization (i.e., overall globalization index, economic globalization index, social globalization index, and political globalization index) on environmental pollution in Central and Eastern European Countries from 1995 to 2015. The findings show that increasing overall globalization, economic globalization, and social globalization increases the carbon emissions while increasing political globalization reduces the environmental pollution. In addition, it is also found that Environmental Kuznets Curve (EKC) hypothesis is confirmed.

As studies mentioned above, impact globalization on environment is not only positive but also negative. The positive impact of the process of globalization on the environment exists to some extent. Among the significant positive impacts of globalization on the environment, the progress in the use of resources, increased environmental awareness, and the development of environmental technology are worth mentioning. The positive impact is reflected in increased awareness of environmental issues and encouraging of multinational companies to take steps to protect the environment. Improved use of resources and preservation of the environment are achieved by promoting growth through sustainable

development, improving education and income. Many multinational companies have focused on the creation of technology that reduces the impact of humans on the environment. Globalization has brought significant conceptual change in the way of thinking about the environment. Many of us now see environmental problems as problems of international significance, not only as a national interest in terms of protection of the oceans and the atmosphere from warming. However, the negative impacts of globalization on the environment outweigh the positive ones. The main causes of environmental problems are: industrial production, growth of energy production, development of traffic, uncontrolled exploitation of natural resources, development of techniques and technology, and chemical contamination of agriculture (Ilić & Hafner, 2015). With the development of society and the increasing population, due to which the demand for products necessary for life increases, it has become necessary to shift to the industrial mode of production. Industrial production certainly has positive sides, in terms of increased production, but, on the other hand, it endangers environment through the emission of harmful gases into the air, water, and soil. Energy production pollutes the air with dust, changes climate. The main pollutants resulting from the increased energy production are: flue gases, fly ash, slag, and waste water. The development of technics and technology leads to industry concentration, which negatively affects the environment. The application of modern technology greatly contributes to global warming and increased emission of harmful gases. In addition, globalization has led to the development of traffic, another cause of environmental degradation. Increasingly developed transport infrastructure has brought a series of environmental problems such as increased air pollution, uncontrolled release of harmful and hazardous substances. The consequences are common in areas with the developed road traffic. Global warming is brought by greenhouse effect, caused by growing industrialization of developing countries and heavy reliance on fossil fuels. The carbon released into the atmosphere in this way causes global warming, which results in ice and glacier melting and consequent sea level rise. Thus, negative impacts are mainly based on export-oriented destruction, as well as on carbon and harmful gases emissions. So there is a vast literature available on relationship between globalization and carbon emission in different countries. From a critical perspective, the use of trade openness or foreign direct investment as an indicator of globalization only covers trade or foreign direct investment intensity. This may lead to mixed and inconclusive empirical findings. However, the emergence of mixed and inconclusive findings will also misguide policy makers in the process of designing policies towards improving environmental quality. To address this issue, this study employs the overall globalization index developed by Dreher (2006), which has been constructed based on sub-indices such as economic globalization, political globalization and social globalization. Next section addresses the methodology used in this study.

### 3. Methodology and data

#### 3.1. Data

In the current study, we employ annual data from 1990 to 2016 in order to achieve targeted research objectives, including CO<sub>2</sub> emissions, globalization, exports, foreign direct investment, coal consumption per capita, and fossil fuels electricity generation series. The time range is limited by the availability of the data. Specific description of the variables is listed in Table 1.

**Table 1**  
Variable description and sources

Variable	Description	Measure	Data source
CO <sub>2</sub>	Carbon dioxide emissions produced during consumption of solid, liquid, gas fuels and gas flaring	Thousands of tonnes	World development indicators
KOF	Overall globalization index includes economic, political and social globalization	KOF index from 0 to 100	KOF index of globalization
FDI	Foreign direct investment	Billion dollars	World development indicators
EX	Exports of goods and services	Billion dollars	World development indicators
COAL	Coal consumption (anthracite, subanthracite, bituminous, subbituminous, lignite, brown coal, oil shale, and net imports of metallurgical coke) per capita	Kilogram per capita	World development indicators
FOSSIL	Fossil fuels electricity generation is electricity generated from fossil fuels	Billion kilowatthours	World development indicators

Source: Author's collection

We convert all the raw data of globalization, exports, foreign direct investment, coal consumption per capita into natural logarithm to effectively address the percentage change of coefficient estimates. The descriptive statistics of variables are shown in Table 2.

**Table 2**  
Descriptive statistics of variables

Variables	Mean $\pm$ SD	Max	Min
CO <sub>2</sub>	75.01259 $\pm$ 49.95466	187.1	17.08
Log(KOF)	3.822898 $\pm$ 0.245128	4.163092	3.33367
Log(FDI)	0.937449 $\pm$ 1.12724	2.533697	-1.7148
Log(EX)	3.236016 $\pm$ 1.357967	5.258484	0.845868
Log(COAL)	5.081061 $\pm$ 0.723425	6.39515	3.926526
FOSSIL	31.43222 $\pm$ 29.3322	94.44	2.27

Source: Author's calculation.

### 3.2. Econometric Methodology

#### 3.2.1. Model specification

The current study aims to investigate the effect of globalization on environment quality in Vietnam. To follow the objective, we apply the empirical model specified in the form:

$$CO_{2t} = \beta_0 + \beta_1 \log(KOF)_t + \beta_2 \log(FDI)_t + \beta_3 \log(EX)_t + \beta_4 \log(COAL)_t + \beta_5 FOSSIL_t + u_t \quad (1)$$

where CO<sub>2</sub> represents carbon dioxide emission; KOF is overall globalization index; FDI refers to foreign direct investment; EX denotes exports; COAL stands for coal consumption per capita; FOSSIL indicates fossil fuels electricity generation; t illustrates year; u<sub>t</sub> designates the white noise error term; and  $\beta_0$  is constant;  $\beta_i$  ( $i = \overline{1,5}$ ) are parameters.

#### 3.2.2. Unit root test

As spurious regression arises in case of nonstationary data, it is significant that all variables are subjected to a unit root test to determine the stationarity properties (i.e., unchanged mean and covariance) of time series. The Augmented Dickey-Fuller (ADF) unit root test is a common tool employed on all variables to check the stationarity and the order of integration. The testing procedure for ADF test is applied to the model:

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{i=1}^p \delta_i Y_{t-i} + \varepsilon_t \quad (2)$$

In this model of equation,  $\Delta$  is the difference operator,  $\alpha$  is a constant,  $\beta$  is the coefficient of time trend,  $p$  is autoregressive order of lag,  $\varepsilon_t$  is white noise. The null hypothesis of ADF test is that a unit root is present in a time series (i.e.  $\gamma = 0$  or the time series is non-stationary) whereas the alternative hypothesis assumes stationarity (i.e.  $\gamma < 0$ ). A series is said to be integrated of order  $t$ , denoted by  $I(t)$ , if one can obtain a stationary series by differencing the series  $t$  times. The notations  $I(0)$  and  $I(1)$  refer to the stationary series at level form or first difference level.

#### 3.2.3. Cointegration and autoregressive distributed lag model

Cointegration involves a certain stationary linear combination of variables which are individually non-stationary but integrated to an order,  $I(d)$ . Cointegration is an econometric concept that mimics the existence of a long-run equilibrium among underlying economic time series that converges over time. Thus, cointegration establishes a stronger statistical and economic basis for empirical error correction model, which brings together short and long-run information in modeling variables. Testing for cointegration is a necessary step to establish if a model empirically exhibits meaningful long run relationships. Engle and Granger(1987) were the first to formalize the idea of cointegration, providing tests and estimation procedure to evaluate the existence of long-run relationship between set of variables within a dynamic specification framework. Cointegration test examines how time series,

which though may be individually non-stationary and drift extensively away from equilibrium can be paired such that the workings of equilibrium forces will ensure they do not drift too far apart. There are several tests of cointegration, other than Engle and Granger (1987) procedure, among them is Autoregressive Distributed Lag cointegration technique or bound cointegration testing technique. Unlike the Engle-Granger and Johansen Juselius cointegration procedures, which require the respective time series be integrated of order one, the ARDL approach to cointegration does not require the variables to be integrated of the same order. Pesaran and Shin (1999) proposed Autoregressive Distributed Lag (ARDL) approach to cointegration or bound procedure for a longrun relationship, irrespective of whether the underlying variables are  $I(0)$ ,  $I(1)$  or a combination of both. Bounds test approach can be applied in two steps. Existence of a long run relationship between the variables in the model is searched in the first step, and the short-term and long-term coefficients of the model are estimated in the second step. At the first step, the existence of the long-run relation between the variables under investigation is tested by computing the Bound F-statistic (bound test for cointegration) in order to establish a long run relationship among the variables. The ARDL unrestricted error correction model approach to cointegration testing is of the form:

$$\begin{aligned} \Delta \text{CO}_2_t = & \alpha + \sum_{i=1}^p \alpha_{0,i} \Delta \text{CO}_{2,t-i} + \sum_{j=0}^{q_1} \alpha_{1,j} \Delta \log(\text{KOF})_{t-j} + \sum_{j=0}^{q_2} \alpha_{2,j} \Delta \log(\text{FDI})_{t-j} + \sum_{j=0}^{q_3} \alpha_{3,j} \Delta \log(\text{EX})_{t-j} \\ & + \sum_{j=0}^{q_4} \alpha_{4,j} \Delta \log(\text{COAL})_{t-j} + \sum_{j=0}^{q_5} \alpha_{5,j} \Delta \text{FOSSIL}_{t-j} + \beta_0 \text{CO}_{2,t-1} + \beta_1 \log(\text{KOF})_{t-1} + \beta_2 \log(\text{FDI})_{t-1} \\ & + \beta_3 \log(\text{EX})_{t-1} + \beta_4 \log(\text{COAL})_{t-1} + \beta_5 \text{FOSSIL}_{t-1} + u_t \end{aligned}$$

where  $\Delta$  is the first difference operator,  $\alpha$  is the drift component and  $u_t$  are the random errors. The null hypothesis of no cointegration ( $H_0$ ):  $\beta_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$  is tested against the alternative hypothesis of cointegration ( $H_1$ ):  $\beta_0 \neq 0, \beta_1 \neq 0, \beta_2 \neq 0, \beta_3 \neq 0, \beta_4 \neq 0, \beta_5 \neq 0$ . However, as discussed by Pesaran et al. (2001), the asymptotic distribution of the F-statistic is non-standard, regardless of whether the variables are  $I(0)$  or  $I(1)$ . Pesaran et al. (2001) provide lower and upper bound critical values, where the lower bound critical values assume all variables are  $I(0)$  while the upper bound critical values assume all variables are  $I(1)$ . If the calculated F-statistic is above the upper critical value, the null hypothesis of no cointegration can be rejected irrespective of the orders of integration of the variables. If the calculated F-statistic is below the lower critical value, the null hypothesis of no cointegration cannot be rejected. However, if the calculated F-statistic falls between the lower and upper critical values, the result is inconclusive. After estimating ARDL model for identifying cointegration, it is essential to confirm the stability of ARDL model in terms of serial correlation, heteroskedasticity, model misspecification, normality. First, serial correlation can be verified by the Breusch-Godfrey Lagrange multiplier test of Breusch and Godfrey (1978). Second, heteroscedasticity is inspected by the Breusch and Pagan test (Breusch and Pagan, 1979). Third, model misspecification can be detected through the Ramsey's RESET test (Ramsey, 1969). Fourth, the normality is checked by the Jarque-Bera test (Gujarati and Porter, 2009). Finally, Cumulative Sum of Recursive Residuals (CUSUM) and cumulative sum of square of recursive residuals (CUSUMSQ) tests are utilized to ensure the stability of the coefficients. When the stability of the ARDL model is acknowledged, short-run and long-run estimations can be initiated. If cointegration is established, the following conditional ARDL model to investigate the effects of the independents variables on the dependent variable is estimated for the purpose of determining the values of the coefficients of the independent variables in the long run.

$$\begin{aligned} \text{CO}_2_t = & \gamma + \sum_{i=1}^p \gamma_{0,i} \text{CO}_{2,t-i} + \sum_{j=0}^{q_1} \gamma_{1,j} \log(\text{KOF})_{t-j} + \sum_{j=0}^{q_2} \gamma_{2,j} \log(\text{FDI})_{t-j} + \sum_{j=0}^{q_3} \gamma_{3,j} \log(\text{EX})_{t-j} + \sum_{j=0}^{q_4} \gamma_{4,j} \log(\text{COAL})_{t-j} \\ & + \sum_{j=0}^{q_5} \gamma_{5,j} \text{FOSSIL}_{t-j} + \varepsilon_t \end{aligned}$$

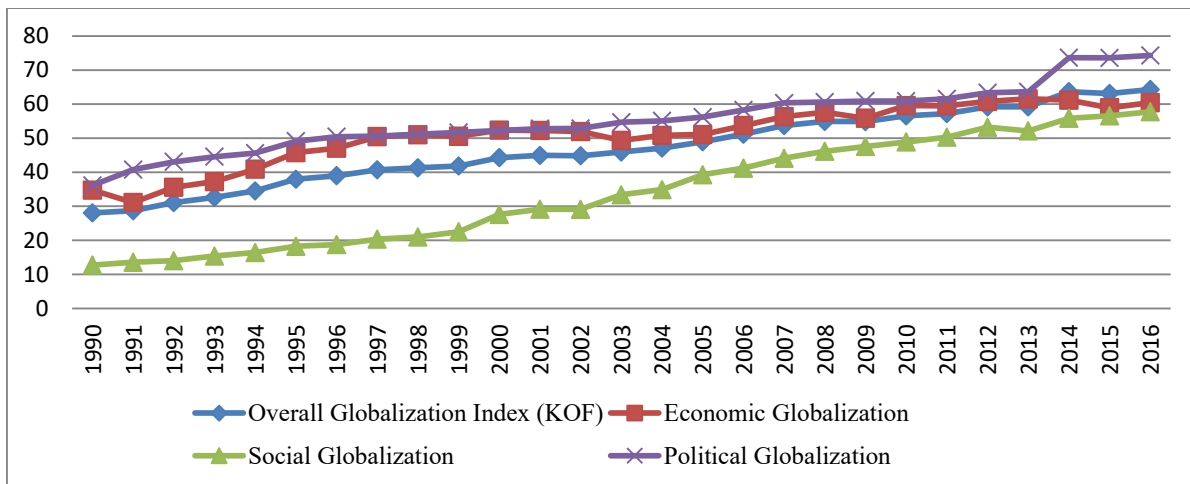
The short-run dynamic parameters are obtained by estimating an error correction model associated with the long-run estimates:

$$\Delta\text{CO}_{2t} = \theta + \sum_{i=1}^p \theta_{0,i} \Delta\text{CO}_{2t-i} + \sum_{j=0}^{q_1} \theta_{1,j} \Delta\log(\text{KOF})_{t-j} + \sum_{j=0}^{q_2} \theta_{2,j} \Delta\log(\text{FDI})_{t-j} + \sum_{j=0}^{q_3} \theta_{3,j} \Delta\log(\text{EX})_{t-j} \\ + \sum_{j=0}^{q_4} \theta_{4,j} \Delta\log(\text{COAL})_{t-j} + \sum_{j=0}^{q_5} \theta_{5,j} \Delta\text{FOSSIL}_{t-j} + \mu \text{ECM}_{t-1} + \epsilon_t$$

where residuals  $\epsilon_t$  is independently and normally distributed with zero mean and constant variance,  $\text{ECM}_{t-1}$  is the error correction term,  $\mu$  is a parameter that indicates the speed of adjustment to the equilibrium level after a shock. It shows how quickly variables converge to equilibrium and it must have a statistically significant coefficient with a negative sign.

#### 4. Results and discussion

Vietnam experienced an increase in the globalization level during 1990 – 2016. In 2016, Vietnam sat at the 82<sup>nd</sup> position with the overall globalization index (KOF) of 64.27. In the three globalization components, Vietnam is ranked 92<sup>nd</sup> in terms of economic globalization, 75<sup>th</sup> in political globalization, and 129<sup>th</sup> in social globalization in the world. It is apparent that the country gave the priority on the political aspect as compared to economic and social aspects.



**Fig. 1.** Development of globalization in Vietnam

During the rapidly globalized period 1990 – 2016, Vietnam witnessed a sharp rise in exports of good and services from 2.33 billion dollars to 192.19 billion dollars and in foreign direct investment from 0.18 billion dollars to 12.6 billion dollars. Energy demand represented by coal consumption per capita and fossil fuels electricity generation dramatically soared from 67.1 kg to 598.8 per head and 3.14 billion kilowatt-hours to 94.4 billion kilowatt-hours, respectively during 1990 – 2016. Vietnam, therefore, had to deal with the diminishing environmental quality as evidenced by the substantial increase of carbon dioxide emission from 17.4 thousands of tonnes in 1990 to 187.1 thousands of tonnes in 2016. Expressly, globalization could pose a major threat to the environment. To understand the effect of globalization on the extent of carbon dioxide emissions in Vietnam, we follow the steps as pointed out in the methodology section.

##### 4.1. Unit root test results

First, Augmented-Dickey Fuller unit root test is employed for level of all variables of interest followed by on the first difference. The results in Table 3 show that  $\text{CO}_2$  emissions,  $\log(\text{KOF})$ ,  $\log(\text{FDI})$ ,  $\log(\text{EX})$



and fossil fuels electricity generation are non-stationary at level while  $\log(\text{COAL})$  is stationary at level. The table also indicates all variables except  $\log(\text{COAL})$  are stationary at the first difference and integrated of order 1. Thus, all considered variables are not integrated at second level of difference. This suggests that the application of ARDL model is appropriate.

**Table 3**  
ADF Unit root test results

Variables	Level		1 <sup>st</sup> Difference		Results
	t-statistic	Prob.	t-statistic	Prob.	
CO <sub>2</sub>	-0.974116	0.9275	-5.614958	0.0009	I(1)
Log(KOF)	-2.079221	0.5327	-5.985979	0.0003	I(1)
Log(FDI)	-2.431943	0.3557	-3.659567	0.0447	I(1)
Log(EX)	-1.983751	0.5826	-4.745794	0.0044	I(1)
Log(COAL)	-5.038816	0.0023			I(0)
FOSSIL	-1.216684	0.8857	-5.477060	0.0008	I(1)

#### 4.2. Bound test result for cointegration

The result of ARDL bound test for the presence of cointegration shown in the Table 4 suggests the rejection of null hypothesis of no long-run relationship at 5% level of significance when CO<sub>2</sub> is treated as dependent variable and  $\log(\text{KOF})$ ,  $\log(\text{FDI})$ ,  $\log(\text{EX})$ ,  $\log(\text{COAL})$ , FOSSILGE are independent variables. That means, there is a long-run equilibrium relationship between CO<sub>2</sub> emissions and its determinants as the calculated F-statistic value 4.006816 is evidently greater than the upper bound critical value of 3.79.

**Table 4**  
Result of ARDL Bound test for cointegration

Test Statistic	Value	K
F-statistic	4.006816	5
Significance	I(0) Bound	I(1) Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

Null Hypothesis: No long-run relationships exist

#### 4.3. Autoregressive distributed lag model estimates

The ARDL model is estimated from a recursive search of optimal number of lags through the Akaike information criterion (AIC) and from the diagnostic statics. Given the yearly data available for estimation, we set the maximum lag order of the various variables in the model equal to two. The optimal model can be selected by using the selection criteria like Akaike Information Criteria (AIC). Table 5 presents the optimal model ARDL(1,1,0,0,1,1) estimates.

**Table 5**  
Autoregressive distributed lag model estimation results

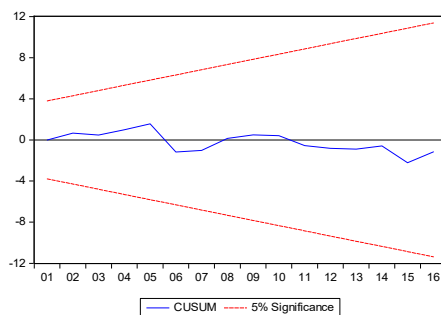
Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO <sub>2</sub> (-1)	0.4173	0.2170	1.9227	0.0725
Log(KOF)	49.2811	26.6897	1.8464	0.0834
Log(KOF)(-1)	58.9391	21.5562	2.7342	0.0147
Log(FDI)	-1.1010	1.5165	-0.7260	0.4783
Log(EX)	-21.3397	6.1945	-3.4449	0.0033
Log(COAL)	14.3446	5.6162	2.5542	0.0212
Log(COAL)(-1)	-11.4283	5.2660	-2.1702	0.0454
FOSSIL	0.8233	0.1182	6.9634	0.0000
FOSSIL(-1)	0.3012	0.2682	1.1232	0.2779
C	-345.3739	76.0884	-4.5391	0.0003
R-squared	0.998688	F-statistic		1353.017
Adjusted R-squared	0.997950	Prob(F-statistic)		0.0000
S.E of regression	2.244640	Durbin-Watson stat		2.110245

*Dependent variable: CO<sub>2</sub>*

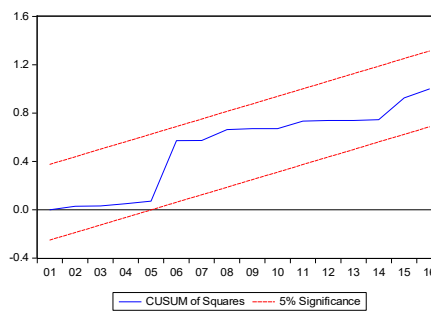
The obtained results show that the overall globalization index significantly and positively influenced the CO<sub>2</sub> emissions in Vietnam. The estimated results of the ARDL model indicate that an increase of overall globalization index level as big as 1 percent will increase CO<sub>2</sub> emissions by 0.49281 thousands of tonnes, *ceteris paribus*. This result is not in line with the study by Le et. al (2018) that found the negative and significant impact of overall globalization index on CO<sub>2</sub> emissions in Vietnam during 1980 – 2015. Exports was found to influence significantly and negatively the CO<sub>2</sub> emissions with coefficient score of -21.33972. This implies an increase in the export level of 1 percent will lead to the decrease of CO<sub>2</sub> emissions by 0.213 thousands of tonnes, *ceteris paribus*. The estimated results show the positive effects (14.34463 and 0.823331, respectively) of coal consumption per capita and fossil fuels electricity generation on CO<sub>2</sub> emissions. Energy consumption positively influenced the CO<sub>2</sub> emissions as it is one of the major inputs for economic growth in Vietnam. In literature, energy consumption is the major source of greenhouse gas emissions. The positive influence of energy consumption on CO<sub>2</sub> emissions is in accordance with theoretical expectation. Foreign direct investment has negative effect on CO<sub>2</sub> emissions in Vietnam but the estimated coefficient is statistically insignificant. That means that foreign direct investment has insignificant impact on CO<sub>2</sub> emissions in long run. Moreover, the lag of CO<sub>2</sub> positively affects CO<sub>2</sub> emissions. Notably, the lag of log(KOF) has a considerable positive impact on the change in CO<sub>2</sub> emissions. The coefficient of the lag of log(COAL) is -11.4283, which is statistically significant at the 5 percent level. The R<sup>2</sup> adjusted result reveals that more than 99% of the total variation of CO<sub>2</sub> emissions can be explained by changes in the level of globalization and remaining explanatory variables. Also, the F-statistic results show that the simultaneous interaction of globalization levels and other variables have significant effects on CO<sub>2</sub> emissions in Vietnam during the review period. To ensure the goodness of fit of the model, diagnostic and stability tests are conducted. The results of diagnostic tests are represented in table 6. The ARDL model passes the Ramsey test for functional form misspecification (p-value of Ramsey test is 0.6110). To identify the problem of heteroskedasticity, the Breusch-Pagan-Godfrey test shows that the variance of unobserved error was constant (p-value of the test is 0.6310). Also, the Breusch-Godfrey Serial correlation LM test used to find out whether the model is free from autocorrelation problem shows that the residuals are serially uncorrelated (p-value of this test is 0.1490) and model do not have the problem of autocorrelation. The normality test indicates the score of Jarque-Bera probability was (0.757781) larger from  $\alpha = 5\%$  and it can be concluded that the model (1) would distribute normally. Thus four components of diagnostic tests as presented in table 6 show that there is no issue with our ARDL model. This evidence indicates that the relationship between CO<sub>2</sub> and the explanatory variables is verified.

**Table 6**  
Diagnostic test results

Types of test	Test statistic	P value
Serial correlation	F-statistic = 2.187944	0.1490
Heteroscedasticity	F-statistic = 0.788621	0.6310
Functional form	F-statistic = 0.269837	0.6110
Normality	Jarque-Bera = 0.554722	0.757781



**Fig. 2.** Plot of cumulative sum of recursive residuals



**Fig. 3.** Plot of cumulative sum of squares of recursive residuals

The stability test is conducted by employing the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ). Fig. 2 and Fig. 3 plot the results for CUSUM and CUSUMSQ tests for the stability of the model. The results indicate the absence of any instability of the coefficients because the plot of the CUSUM and CUSUMSQ statistic fall inside the critical bands of the 5% confidence interval of parameter stability. The null hypothesis of all coefficients in the given regression is stable can not be rejected, thus short-run and long-run coefficient estimations is reliable at 5% significance level.

#### 4.4. Estimated long run coefficients

Table 7 presents the solved static long run coefficients of the ARDL model. The estimated coefficient of 185.7176 shows that globalization has positive and significant effect on CO<sub>2</sub> emissions in long run. This means that an increase in overall globalization index as big as 1 percent is associated with an increase of CO<sub>2</sub> emissions by 1.857 thousands of tonnes, ceteris paribus. The long run test statistics reveal that globalization is the key determinant of the CO<sub>2</sub> emissions. Our finding completely contradicts the earlier findings reported by Le et al. (2018). In addition, exports significantly and negatively affected CO<sub>2</sub> emissions on the degree of 10 percent with the coefficient of -36.6213. Fossil fuels electricity generation was found to exert positive impact on CO<sub>2</sub> emissions in Vietnam. FDI and coal consumption percapita have statistically insignificant effect on CO<sub>2</sub> emissions in long run.

**Table 7**

Estimated long run coefficients of the ARDL approach

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Log(KOF)	185.7176	79.1257	2.3471	0.0321
Log(FDI)	-1.8894	2.4571	-0.7689	0.4531
Log(EX)	-36.6213	20.2578	-1.8078	0.0895
Log(COAL)	5.0048	10.8463	0.4614	0.6507
FOSSIL	1.9298	0.3095	6.2350	0.0000
C	-592.6991	255.6362	-2.3185	0.0340

#### 4.5. Estimated short run coefficients of error correction model

With the acceptance of long run coefficients of CO<sub>2</sub> emissions equation, the short run coefficients are estimated. The results are presented in Table 8.

**Table 8**

Error correction representation for ARDL model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(Log(KOF))	49.2811	26.6897	1.8464	0.0834
D(Log(FDI))	-1.1010	1.5165	-0.7260	0.4783
D(Log(EX))	-21.3397	6.1945	-3.4449	0.0033
D(Log(COAL))	14.3446	5.6162	2.5542	0.0212
D(FOSSIL)	0.8233	0.1182	6.9634	0.0000
ECM(-1)	-0.5827	0.2170	-2.6849	0.0163

Estimation results show that the short run coefficients of all the regressors are statistically significant, except the coefficient of foreign direct investment variable is statistically insignificant. The estimated coefficient of globalization indicates that globalization has positive effect on CO<sub>2</sub> emissions in short run. This implies that a change in the globalization (D(log(KOF))) is positively associated with a change in the CO<sub>2</sub> emissions in the short run. Similarly, a change in the coal consumption per capita (D(Log(COAL))) and fossil fuels electricity generation (D(FOSSIL)) have a statistically significant positive effect on the change in CO<sub>2</sub> emissions. Thus, energy consumption positively influenced the CO<sub>2</sub> emissions in short run. The estimated results also show that a change in exports (D(log(EX))) is negatively associated with CO<sub>2</sub> emissions and its estimated coefficient is statistically significant at 1%. The results in Table 8 clearly show that the error correction variable (ECM) was significant validating the error correction model specification. The coefficient of error correction term has negative sign (-0.582714) as expected and it is significant at 5% level. Error correction term shows how fast the model

returns to stability at any disturbance or shock. The speed of adjustment between short run dynamics and long run equilibrium value is 58% meaning about 58% of the discrepancy between long term and short term CO<sub>2</sub> emissions is corrected within a year (yearly data). The significance of the coefficient of ECM connotes the existence of a long run equilibrium relationship between CO<sub>2</sub> emissions and the explanatory variables.

## 5. Conclusions and Recommendations

This study empirically examined the impact of globalization on CO<sub>2</sub> emissions in Vietnam in the period 1990–2016 by employing autoregressive distributed lag approach to cointegration analysis. The absence of I(2) variables was ensured by utilizing the ADF test, which validates the appropriate use of the ARDL model for further analysis. The results based on the bounds testing procedure confirm that a stable, long run relationship exists between CO<sub>2</sub> emissions and its determinants: globalization, exports, foreign direct investment, coal consumption per capita and fossil fuels electricity generation. After confirming the long run equilibrium among variables, the short run coefficients are estimated by an error correction model developed within an ARDL framework. In terms of key empirical findings, we conclude that globalization increases carbon emissions in Vietnam and globalization is not beneficial for the long-term environmental health. This finding is consistent with the result of Dinda (2006) that globalization increases CO<sub>2</sub> emissions, which is the main culprit of global warming. This result is also in line with the finding of Shahzadi et al. (2019). Thus, the findings of this paper support previous literature on the positive impact of globalization on environmental degradation. However, our findings contradict the conclusion of Le et al. (2018) about the negative and significant impact of globalization on CO<sub>2</sub> emissions in Vietnam during 1980 – 2015. The study further showed that exports lowers CO<sub>2</sub> emissions in both short run and long run whereas coal consumption per capita and fossil fuels electricity generation raise CO<sub>2</sub> emissions. Moreover, there is no evidence to prove that foreign direct investment has direct effect on CO<sub>2</sub> emissions in Vietnam in short run as well as in long run.

In terms of key policy implications, we suggest that government may use proper and effective policy coordination to minimize the environmental cost caused by globalization. Given the harmful environmental consequences of globalization, we suggest that policy makers should not underestimate the role of globalization in the dynamics of carbon emissions in Vietnam when designing comprehensive and long-term environmental policy framework. We further suggest that policy makers in Vietnam should consider “globalization” as a key economic tool in our environmental policy framework to improve the quality of environmental health in the long run. In addition, Vietnam needs to enhance our energy-related research and consider the wider role of globalization in energy demand and emissions functions. The use of cleaner and alternative technologies through innovation, investment and international collaborations can also play a vital role in achieving low carbon-driven sustainable environment-friendly economic growth in the long run.

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