Journal of Cleaner Production 228 (2019) 533–543

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Dynamic linkages between globalization, financial development and carbon emissions: Evidence from Asia Pacific Economic Cooperation countries

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A R T I C L E I N F O

Article history:
Received 4 February 2019
Received in revised form
11 April 2019
Accepted 18 April 2019
Available online 24 April 2019

Keywords:
Carbon emissions
Globalization
Financial development
Asia pacific economic cooperation (APEC)

A B S T R A C T

This study determines the dynamic linkages between globalization, financial development and carbon emissions in Asia Pacific Economic Cooperation (APEC) countries in the presence of energy intensity and economic growth under the framework of Environment Kuznets Curve (EKC). This study employs the panel data from 1990 to 2016, Westerlund cointegration technique to find long-run cointegration, and Continuously Updated Bias-Corrected (CUP-BC) and Continuously Updated Fully Modified (CUP-FM) methods to check the long-run elasticities between the variables. Empirical results indicate that globalization and financial development significantly reduce carbon emissions, but economic growth and energy intensity increase them. These results support the EKC hypothesis for APEC countries. The Dumitrescu and Hurlin causality analysis shows that globalization Granger causes CO_2 emissions. Globalization also causes financial development and energy intensity. A feedback effect exists between financial development and CO_2 emissions. Furthermore, financial development causes economic growth but similar is not true from opposite-side in Granger sense. Finally, this study presents important policy implications with respect to APEC countries.

1. Introduction

Increasing rates of growth have become a challenge for every country. In pursuit of economic growth, countries have signed agreements of economic cooperation, which have increased globalization throughout the world. Asia Pacific Economic Cooperation (APEC) agreement is one such agreement. APEC member countries seek to increase economic growth via trade openness, development projects, interactive technology, and skill transfer, etc.

In economic terms, globalization is the process through which corporations, governments, and other organizations around the world increasingly interact. The system, whose modern form took shape in the 1970s, has promoted worldwide growth in trade, increase in capital and innovations, and the spread of cultural, social, and political values (Shahbaz et al., 2017b). Every human is affected by globalization in some form, whether through changes in energy consumption and intensity, use of technology, foreign direct investment, employment, industrial expansion or contraction, or environmental alterations. Among these changes, economic growth and environmental changes are the most challenging. Whether economic groups like APEC can increase growth rates with the help of globalization without damaging environment is a critical question.

Opinions about the effects of globalization on environment are different such as some support globalization without regard to environment, and others oppose it. Globalization-supporters argue that globalization benefits economies and those environmental issues are simply the trade-offs. Globalization certainly has multiple benefits, such as when multinational companies that share their best practices with host countries. Globalization also increases foreign direct investment, and can even lead transfer of environment friendly, innovative, green technologies from developed to

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https://doi.org/10.1016/j.jclepro.2019.04.210
0959-6526/

developing countries (Christmann and Taylor, 2001). Furthermore, the emerging concept of global information and shared knowledge has increased awareness of ecological issues and mobility of resources. Economic development can be achieved via institutional development, and globalization is a strong weapon in such development efforts (Mishkin, 2009). To create wealth, nations should remain open to rest of the world, as innovative products, investment, and new ideas will come to host countries, generating wealth and raising per-capita income. However, as Mishkin (2009) pointed out, the positive impact of globalization is possible only if certain fundamental institutions are active in the countries.

On the other side, opponents of globalization hold that globalization's benefits in developed economies have come in large part at the cost of middle class, which has significant political, social, and stable implications that will continue to be felt in coming decades. Shahbaz et al. (2017a) viewed globalization as the source of global warming that reduces access to natural resources; as Anyweiler et al. (2001) pointed out, when trade liberalization increases, governments are compelled to reduce their production costs by neglecting or sacrificing their environments. According to Ghosh (2010), developing countries suffer from globalization because they have weak institutional quality and environmental standards, so they face negative effects in the form of environmental degradation. What's more, when large economies outsource production capacity, the percentage of imports consumed in those countries rises, and domestic production decreases. An increase in import consumption correlates with a decrease in jobs for middle and lower classes.

Another important determinant of environmental quality is ‘financial development’. As Per Mishkin (2009) and Shahbaz et al. (2018b), globalization leads financial development, but some studies have suggested that financial development increases CO_2 emissions because it reduces the credit constraints in the economy and lifts Gross Domestic Product (GDP), consequently increasing CO_2 emissions. As Sadorsky (2010) explained, efficient financial intermediation increases access to lending, enabling customers to buy expensive items like vehicles that increase carbon emissions. Dasgupta et al. (2001) stated that stock market development lowers financing costs and improves firms' liquidity, enabling them to increase productivity, thus increasing energy use and CO_2 emissions. Another group of researchers favors financial development because it amplifies investments in modern technology that may reduce carbon emissions (Shahbaz et al., 2016b; Zafar et al., 2019a). Therefore, this study also incorporates financial development in discussing the role of globalization and CO_2 emissions. Excluding this critical factor could raise questions about the reliability of empirical results.

Energy intensity refers to the quantity of energy that is needed to produce one unit of output (The Conference Board of Canada, 2015). Since energy equates to the conversion cost of energy into economic growth, it is often used as a proxy for energy consumption and is considered central to globalization (Overland, 2016). Using energy intensity, researchers like Shahbaz et al. (2016c) have reported a long-term linkage between energy intensity and CO_2 emissions. When globalization comes with innovative technology, it improves the host country's energy intensity. High-energy intensity refers to a high energy-to-GDP conversion cost such that higher the amount of energy required for one unit of production, the higher energy intensity (Nabavi-Pelesaraei et al., 2014a). Calculations of the net results of globalization are more reliable when energy intensity is considered in carbon emissions function.

For this purpose, we use the APEC group of countries. According to the International Energy Agency (IEA, 2017), APEC countries account for 57 percent of the world's GDP, while their electricity consumption accounts for 60 percent of the world's electricity consumption, and they hold a 47 percent share of world trade. Therefore, their policies may affect many countries' GDP directly. The rising energy demand of these countries (growth rate of 2.1%) indicates that they are increasing their trade activities, which may increase environmental problems in these economies (Le et al., 2017). The APEC economies have experienced considerable economic development by adopting globalization, as is evident from their economic performance. Such development requires efficient responses from the business community and government, as the APEC countries are seeking to advance their prosperity by opening their borders to trade and creating opportunities for foreign direct investment (FDI) in their economies (Zafar et al., 2019b). The economic interdependence of APEC countries has raised their living standards. However, significant changes in energy consumption occur when globalization takes effect in any country. Therefore, there is a need to determine the linkages between globalization and carbon emissions in these countries by considering the contributing role of financial improvement and energy intensity, which is the core concern of our research.

CO_2 emissions' link with globalization and financial development has gained little attention in the literature. For instance, Magazzino (2017) probed the nexus of energy use, GDP, and carbon emissions in the APEC region using the Vector Auto Regression (VAR) approach and found no causal relationship between GDP and energy use. Similarly, Zafar et al. (2019a,b) investigated the EKC in APEC countries but did not check the role of energy intensity. The pros and cons of globalization in APEC countries should be studied, especially from environment point of view, as knowing the effects of globalization on environmental quality and economic growth, APEC countries may restructure their trade policies, inward FDI, and environmental policies to ensure sustainable economic growth. From the methodology perspective, studies have used first-generation methodology to examine unit root properties, but we examine dynamic long-run equilibrium relationship using the second-generation Westerlund's panel cointegration test. To analyze long-run output elasticities, we use continuously updated fully modified (CUP-FM) and continuously updated bias-corrected (CUP-BC) methods, as well as Dumitrescu and Hurlin's tests to determine the paths of causal interactions.

The remainder part of this study proceeds in the following sequence. Section-II contains a literature review, data and theoretical framework are presented in section-III, Section-IV presents the results and discussion, along with important policy implications, and Section-V presents concluding remarks.

2. Literature review

Numerous inconclusive studies have attempted to describe the nexus of globalization, financial development, and CO_2 emissions. For example, Zafar et al. (2019a) investigated this nexus for OECD countries, while Ghosh (2018) studied Asian countries, Haseeb et al. (2018) studied BRICS countries, Saud and Chen (2018) explored the relationship for China, Shahbaz et al. (2017b) did so for Japan, and Shahbaz et al. (2018d) explored this nexus for developed economies. This section presents a pairwise literature review to present the existing work of researchers.

2.1. Globalization—Carbon emissions nexus

There is scant literature available that addressed the linkage between globalization and CO_2 emissions. Lee and Min (2014) probed this link using panel data from 1980 to 2011 and reported that globalization curtails the environmental deterioration in the participating countries. Bu et al. (2016) studied this nexus for 166 countries during 1990–2009 period and observed that the dimensions of globalization play an active role in environmental degradation, although the effects for OECD and non-OECD countries differ widely. Shahbaz et al. (2016a,b,c) examined the extent to which globalization affects CO_2 emissions in African countries using Auto Regressive Distributive Lag (ARDL) and Pooled Mean Group (PMG) methodologies for analysis. Their results indicated that globalization decreases the intensity of CO_2 emissions in the panel as a whole, but results are different for each country. In another study, Shahbaz et al. (2015) explored this link for India and found a negative impact of globalization (and all of its dimensions) on environmental quality.

Similarly, using data from Malaysia for 1970 to 2014, Solarin et al. (2017) measured globalization through the agreement of Trans-Pacific Partnership (TPP) and examined its impact on environmental quality. Their results of ARDL and FMOLS approaches showed that globalization accelerates the level of CO_2 emissions. An empirical study of Shahbaz et al.'s (2017a,b,c) on this relationship covered the period from 1970 to 2014 for Japan and confirmed asymmetric cointegration through N-ARDL approach. They concluded that CO_2 emissions and globalization are directly proportional to each other, whether decreasing or increasing.

You and Lv (2018) used data from eighty-three countries over the 1985–2013 period to test this nexus. They reported that carbon emissions pose spillover effects on neighboring countries. Their results of the spatial regression indicated a negative impact of economic globalization on CO_2 emissions. Haseeb et al. (2018) used the Dynamic Seemingly Unrelated Regression (DSUR) technique and probed the associations among globalization, financial development, energy use, urbanization, and CO_2 emissions for BRICS economies covering the period from 1995 to 2014. They reported null link of globalization with CO_2 emissions for the BRICS panel, and the time series data in their study showed globalization significantly accelerates the CO_2 emissions in Russia and India, whereas significantly improves the environmental quality for the countries Brazil, China, and South Africa. Shahbaz et al. (2018a,b,c,d,e) also checked this globalization-emissions nexus for twenty-five developed countries using the AMG and Common Co-related Effects Means Group estimator (CCEMG) approaches to control heterogeneity in cross-section panel data from 1970 to 2014. Their findings showed that globalization positively affects environmental degradation. Xu et al. (2018) investigated the influence of globalization (including all of its dimensions) on carbon emissions for Saudi Arabia using data from 1971 to 2016 and the ARDL approach. Their results suggested that economic globalization increases CO_2 emissions, but other globalization components do not. Salahuddin et al. (2019) studied Sub-Saharan African countries to probe the links among globalization, urbanization, and environmental quality. Their panel methodology results suggested no significant effect of globalization on environmental quality however, urbanization impedes environmental quality. Destek (2019) found an impact of political, economic and social globalization on carbon emissions by covering annual periods 1995–2015 for Central & Eastern European Countries (CEECs). They employed the AMG technique for a long-run estimation and found that economic globalization and overall globalization increase CO_2 emissions, whereas political globalization decreases it.

2.2. nexus of financial development & carbon emissions

Although financial sector development is fundamental in increasing the economic growth in a country, however, its negative environmental effects and ecological implications cannot be overlooked, as it affects energy consumption, GDP, and environmental quality (Charfeddine and Ben Khediri, 2016). With an increase in financial sector development, energy consumption is also increased. For example, availability of finances improve the living standards of citizens and enhance human activities that increase energy consumption. Shahbaz et al. (2017a) argue that financial development is useful in attracting more FDI in the country that results in more economic growth and energy consumption. But on the other hands, financial development combined with modern technology can reduce energy use and environmental pollution. Some proponents have argued that financial development is beneficial for environment because of its potential to reduce CO_2 emissions. For example, using panel methodology for BRICS countries, Tamazian et al. (2009) found a negative link between CO_2 emissions and financial development during the 1992–2004 period. For the case of China, during the 1953–2006 period, Jalil and Feridun (2011) used the ARDL method and report that, with each increment of financial development, environmental quality also improves, perhaps because of reduction in CO_2 emissions. Employing a related technique, Shahbaz et al. (2013) found similar consequences for South Africa and Indonesia. Saidi and Mbarek (2017) also studied this nexus using the generalized method of moments (GMM) method for emerging economies and reported positive role of financial development in improving environmental quality. Shahbaz et al. (2018a,b,c,d,e) inspected effect of financial development, energy innovativeness, and FDI on environmental quality in France during the period from 1955 to 2015 and found that financial development and innovation in energy production increase environmental quality, while FDI decreases it. Using ARDL, Salahuddin et al. (2018) reported a negative linkage of financial development with environmental quality for the state of Kuwait.

The second group of researchers considers financial development to be harmful to environmental quality. For example, Boutabba (2014) reported a positive contribution of financial development in environmental degradation in India, and Al-Mulali et al. (2015) reported the same contribution for a panel of twenty-three European countries for the period from 1990 to 2013. Charfeddine and Ben Khediri (2016) also endorsed the findings of (Al-Mulali et al., 2015) by studying the case of UAE covering the time span 1975–2011. By employing asymmetric approach, Shahbaz et al. (2016a,b,c) also investigated the same nexus in the presence of GDP and energy consumption in Pakistan. They introduced a financial development index based on stock market and banking indicators. They reported that a rise in the banking development index accelerated the carbon emissions in Pakistan. Bekhet and Othman (2017) also checked the contribution of financial development in CO_2 emissions for Malaysia using ARDL and stated that financial development increases CO_2 emissions. Pata (2018) employed a similar approach to Turkey and found that financial development enhanced carbon emissions when the EKC hypothesis applies. Using panel data methodology, Zakaria and Bibi (2019) considered the links among financial development, institutional quality, and environment quality and showed that financial development significantly decreases environmental quality, while institutional quality increases it. More recently, Charfeddine and Kahia (2019) employed the Panel-Vector Autoregressive (PVAR) approach to twenty-four MENA countries and explained a positive contribution of financial development in accelerating the level of carbon emissions.

2.3. economic growth-carbon emissions nexus

The existing literature extensively uses the concept of Environment Kuznets Curve (EKC) to describe the linkage of economic growth and carbon emissions. Grossman and Krueger (1995) are considered pioneers for finding the long-run relationship between environment and income per capita. The inverted U-shaped of the EKC proposes that, when an economy first improves, the rise in economic growth increases environmental deterioration, but when economic growth approaches a specific limit, additional rise in economic growth then causes improvement in environmental quality (Charfeddine and Mrabet, 2017). The reason for this threshold may be the technology effect (Danish et al., 2018). Dogan and Seker (2016) explored the link between real output and CO_2 emissions in case of OECD countries and supported the EKC. Apergis and Payne (2009) investigated the nexus of EKC and energy consumption for spanning 1971–2004 in Central American states. Their results of Pedroni tests for cointegration and FMOLS showed support for the EKC hypothesis, which is the main framework in investigating the growth-environment nexus (Canas et al., 2003).

Prior studies have used various types of emissions to measure ecological degradation. In single-country analyses, a surplus of empirical investigations validated the EKC hypothesis and reported a U-shaped linkage of income with CO_2 emissions, for instance, Balaguer and Cantavella (2016) for Spain, Seker et al. (2015) for Turkey, Katircioğ;lu (2014) for Singapore, Li et al. (2016) for China, Shahbaz et al. (2014) for Tusnia, Tang and Tan (2015) for Vietnam, and Alam et al. (2016) for Brazil, China, India, and Indonesia. Similarly, several studies have found support for the EKC hypothesis for panel data sets, such as Apergis (2016) for fifteen countries (Zafar et al., 2019a), for OECD countries, Arouri et al. (2012) for MENA countries, and Zaman et al. (2016) for developed and developing countries. On the contrary, some studies such as Ajmi et al. (2015) for G7 countries, Alege et al. (2016) for Nigeria, Ali et al. (2017) for Pakistan, Dogan and Turkekul (2015) for the United States did not find support for the EKC. Clearly, these studies presented inconclusive and mixed results.

Some scholars have used energy intensity instead of energy consumption to measure total consumption of energy (See, for example, Shahbaz et al., 2016c). Energy intensity reflects the efficiency or inefficiency of an economy's energy use such that economies that use less energy to produce goods and services also have lower energy intensity (Kaab et al., 2019). Energy intensity is used to convert energy into economic growth, so its role in carbon emissions is critical. According to Shahbaz et al. (2016c), energy intensity reflects the level of technological advancement in a country and positively affects environmental degradation in the context of African countries.

Numerous studies have investigated the determinants of environmental quality for the APEC region. Zhang et al. (2016) checked the EKC in the APEC region by including the effect of corruption in the model. They used quantile regression and confirmed the presence of EKC hypothesis. Magazzino (2017) argued that energy consumption and carbon emissions are related to increased income in APEC countries. Sinha and Sengupta (2019) examined the role of energy mix in nitrous oxide (NO_2) emissions in APEC countries and found N-shaped link between NO_2 emissions and income.

The role of globalization and financial development in the increasing CO_2 emissions has not yet been explored for APEC countries. This topic has garnered increasing interest among researchers, some of whom have presented results for a variety of datasets, including Bu et al. (2016) for OECD & non-OECD countries, Zafar et al. (2019a) for OECD countries, Xu et al. (2018) for Saudi Arabia, and Shahbaz et al. (2017c) for Indian economy. The studies on APEC countries have primarily covered the topics of economic development, energy consumption, and carbon emissions, but there remains a gap in the literature as it relates to examining the contributions of globalization and financial development in carbon emissions. This study fills the literature gap by presenting a rigorous analysis of the APEC region.

The APEC region has not been investigated to find out the effects of globalization and financial sector development on environmental degradation by including controlling GDP and energy intensity. This study helps policymakers in the APEC region to achieve a sustainable environment in the process of globalization and increase their countries' financial development.

3. Data and theoretical framework

3.1. Data

This research work is aimed to find the linkages between globalization, financial development, and carbon emissions, taking energy intensity and economic growth as additional determinants of carbon emissions in the EKC framework. The list of APEC countries includes Australia, Brunei Darussalam, Chile, China, Indonesia, Japan, Malaysia, Mexico, New Zealand, Peru, South Korea, the Philippines, the Russia Federation, Singapore, Thailand, the United States (the US), and Vietnam. Because of missing data for Canada, Hong Kong, and Papua New Guinea, we exclude these countries from the panel. We use the data from the web page of World Development Indicators (World Bank, 2017) in respect to financial development, CO_2 emissions, GDP and energy intensity, while the data for globalization is taken from Dreher (2006), who developed a globalization index based on social, economic, and political globalization. Table-1 describes the detail of variables used in this study.

Note: Data for all variables except the globalization index data are taken from the World Development Indicators (World Bank, 2017). The globalization index data comes from Dreher (2006).

3.2. Theoretical framework

The debate about globalization is not new, and researchers have investigated the effects of globalization for decades, including Grossman and Krueger (1991), who studied the Northern America Free Trade Agreement (NAFTA) and discussed the scale effect, the technique effect, and the composition effect of globalization. The scale effect occurs when production increasing, augmenting foreign trade and investments. With expansion in industrial and trade activities, the pollution level rises, ceteris paribus (Dreher, 2006), so many structural changes take place when the scale effect of globalization comes into play. With the composition effect, increased production leads to increases in investment and harm to environment, as pollution-causing production becomes a motivation for investors to profit. The technique effect of globalization is observed when the economy stabilizes along with the scale of production. At this stage, new technology is adopted and innovative production methods are introduced, and an increase in pollution-free trade and investments reduces CO_2 emissions. When these kinds of structures and economies of scale are considered with new production techniques and technologies, international trade and investment reduce per-unit pollution carbon emissions (Shahbaz et al., 2016a,b,c). Trade liberalization and foreign investment contain positive as well as negative points, as revealed in the decomposition effect. These two dynamics can maneuver in different and parallel directions and can be used to examine ecological impacts empirically.

Another determinant of CO_2 emissions we use in this study is financial development. Financial development and expansion play

Table-1
Detail of variables.

Variable name	Unit of measurement	Definition
Carbon emissions	Metric Tons	The carbon emissions released from using oil, gas, coal and other fuels
Energy Intensity	Kilograms of oil equivalent	Per capita energy use from all sources, divided by per capita economic growth
Per capita Gross Domestic Product	Constant 2010 US $	The value of GDP divided by population
Square of Gross Domestic Product	Constant 2010 US $	The square of per-capita GDP (used to check the EKC hypothesis)
Financial Development	% of GDP	Measured through the proxy "domestic credit issued to Private sector"
Globalization	Index	Social, economic, and political aspects of globalization

a major role in carbon emissions in any country. For instance, Sadorsky (2011) argued that financial development encompasses purchasers' reach for durability and reliability of goods that accelerate energy consumption and environmental degradation. An improved financial system increases capital and supports the business class in expanding their business activities and production capacities as the demand for products and services rise (Charfeddine and Ben Khediri, 2016). Several authors have measured financial development with the help of various proxy variables, but we use the proxy measure suggested by Shahbaz et al. (2018c) while measuring effects on CO_2 emissions for France.

We also use economic growth and energy intensity because the effect of globalization and financial development simply cannot be examined appropriately without these variables. This study uses energy intensity to measure energy consumption. The relationship between economic growth and carbon emissions has been extensively discussed through the EKC, for instance, Ahmad et al. (2016) for the Indian economy, Begum et al. (2015) for Malaysia, Ozturk and Acaravci (2010) for Turkey, Pao and Tsai (2010) for BRICS, and Sinha and Shahbaz (2018) for India.

Following Sadorsky (2010), Topcu and Payne (2017), Destek (2018), Shahbaz et al. (2018a,b,c,d,e), and others, we write following function to estimate carbon emissions:

$$CO_2 = f(GLOB, FD, GDP, \mathrm{GDPS}, \mathrm{EI}) \quad (1)$$

where CO_2 is CO_2 emissions, GLOB is globalization, FD is financial development, GDP is gross domestic product, GDPS is squared term of GDP to measure EKC, and EI is energy intensity. To reduce the sharpness in the data, we take the natural-log of all the variables. In contrast with a simple linear transformation, log-linear model offers empirically consistent and efficient results. We present the augmented multivariate production function for our linear-log model as:

$$\ln CO_{2it} = \beta_0 + \beta_1 \ln GLOB_{it} + \beta_2 \ln FD_{it} + \beta_3 \ln GDP_{it} + \beta_4 \ln GDPS_{it} + \beta_5 \ln \mathrm{EI}_{it} + \varepsilon_{it} \quad (2)$$

Where β represents coefficient, i denotes the countries involved in estimation (1, 2, …, N), t shows the period of analysis (1990–2016), and ε denotes the residual. β_1, β_2, β_3, β_4, and β_5 are the coefficients of *GLOB*, *FD*, *GDP*, *GDPS*, and *EI*, which are globalization, financial development, per-capita GDP, per-capita GDP squared, and energy intensity, respectively. Figure-1 shows the flowchart of econometric analysis used in this study.

4. Results, discussion and policy implications

The descriptive statistics and correlation matrix of the data are presented in Table-2, which shows a positive linkage between globalization & CO_2 emissions, between globalization & financial development, and between financial development & CO_2 emissions. The outcomes also reveal positive co-movement of GDP and CO_2 emissions and a negative correlation between globalization and energy intensity.

We started our empirical analysis by testing the cross-sectional dependence among variables. Without controlling the issue of cross-sectional dependence, the findings are considered biased and unreliable (Paramati et al., 2017), as cross-sectional dependence indicates that countries are connected through channels like shared borders, trade agreements, technology spillover, financial crisis spillover, and many other ways.

Table-3 presents the outcomes of cross-sectional dependence test. The results are significant at 1% significance level and verify the rejection of null hypothesis.

The results shown in Table-3 confirm the presence of cross-sectional dependence among the variables; therefore, we cannot use first-generation unit root tests to examine the variables' integration properties, as these methods have no power to encounter cross-sectional dependence (Liu, 2013). This issue can be addressed by employing the cross-sectional Augmented Dickey-Fuller (CADF) test and the augmented cross-sectional IPS (CIPS) proposed by Pesaran (2007). The null hypothesis means the data is non-stationary whereas the alternative hypothesis states that data is stationary. The optimum lag structure is found through the Schwarz information criterion. Table-4 shows the empirical findings of CIPS and CADF unit root tests. All variables are non-stationary at I(0) but turn stationary at I(1).

Earlier studies used different techniques like Johansen, Kao, and Pedroni's panel cointegration to test long-term linkages. These techniques ignore cross-sectional dependence in data. Westerlund (2007) addressed this dilemma by introducing the Westerlund cointegration techniques that are based on error correction and are free from common-factor restrictions. If null hypothesis is rejected, it means cointegration exists between the variables. Table-5 presents the results of Westerlund Cointegration test.

Table-5 verifies that variables are cointegrated in long-term, as the results are statistically significant at 5 and 10 percent. It shows the confirmation of linkages between globalization, financial development, CO_2 emissions, GDP, GDP^2, and energy intensity in the long-term.

4.1. long-run analysis

Previous studies have employed first-generation methods to estimate long-run elasticities, but these methods ignore the problem of cross-sectional dependence (Ulucak and Bilgili, 2018). To overcome this issue, this study uses CUP-BC and CUP-FM, developed by Bai and Kao (2006). These methods are effective in controlling for cross-sectional dependence among the variables and control for the endogeneity problem, as when a panel consists of weak exogenous variables; CUP-FM and CUP-BC avoid the endogeneity issues (Ulucak and Bilgili, 2018). Our samples are of ample size and have strong power values for applying the two estimators CUP-FM and CUP-BC. These techniques produce robust results even

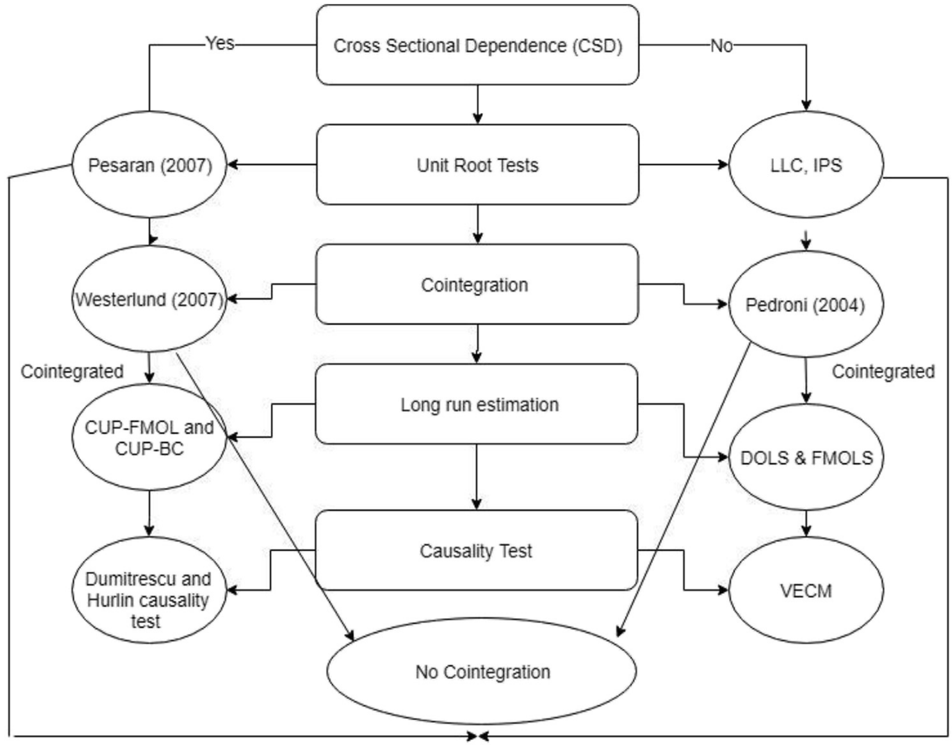

Figure-1. Flowchart of econometric analysis.

if the variables' integration levels are mixed at level or first difference. The CUP-FM repeatedly estimates the parameters and loadings to obtain the convergence level. It assumes that error term chases the factor model. We formulate the factor model as follows:

$$(\widehat{\beta}_{CUP}, \widehat{F}_{CUP}) = \mathrm{argmin}\frac{1}{nT^2}\sum_{i=1}^{n}(y_i - x_i\beta)' M_F(y_i - x_i\beta)$$

where $M_F = I_T - T^{-2}FF'$, $I_T$and F shows the dimension T's identity matrix. Error term assumes latent common factors. Therefore, initial estimates are assigned to F, which repeats until the convergence level is achieved. Figure-2 shows the graphical summary of long-run relationships and Table-6 reveals the outcomes of long-run elasticities.

The link between globalization and CO_2 emissions is significantly negative, as a 1% rise in globalization reduces the level of emissions by 0.0330 percent. This result implies that globalization significantly decreases carbon emissions in APEC countries and suggest that trade openness and inward FDI during the process of

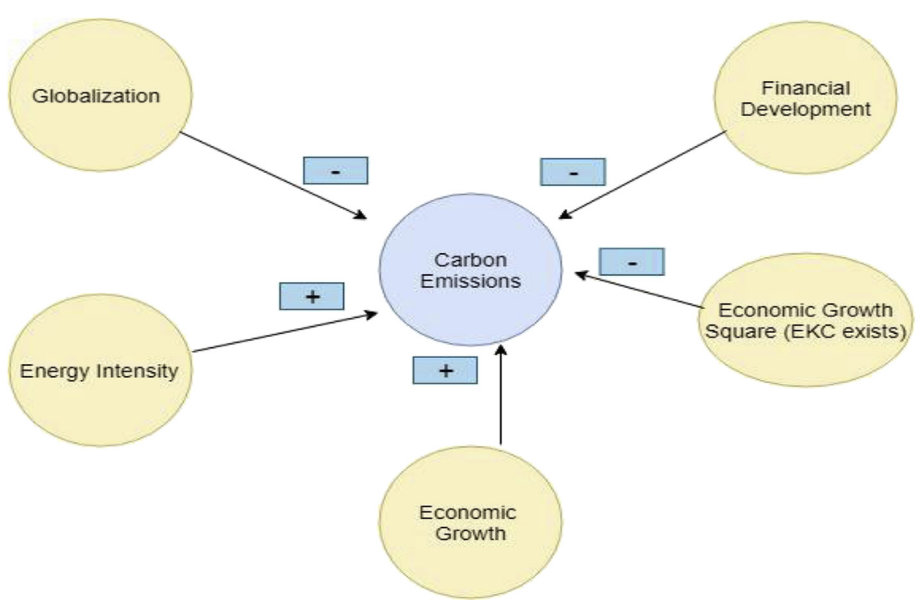

Fig. 2. Long run relationships.

globalization bring energy-efficient technology to APEC countries. The technique effect is in play in each scenario, as globalization brings in innovative products and new production techniques that foster new activity. Globalization can increase economic growth with minimum harm to environment (Shahbaz et al., 2016c), as when there is a global competition, organizations improve their product and service standards so they can be competitive, which helps to address the countries' environmental issues. Our results are similar to those of Shahbaz et al. (2016c), who concluded that globalization reduces carbon emissions when the technique effect takes over the scale effect, but our results contradict the findings of Ghosh (2010), who found a positive role of globalization in environmental deterioration for low- and middle-income Asian countries. Our results also contradict those of Shahbaz et al. (2015), who reported a positive connection between globalization and environmental pollution in India.

This study shows a negative link between globalization and environment, and so makes the following policy recommendations to APEC countries. Environmental quality can be enhanced by adopting openness to markets and new kinds of trading partners. Pollution can be reduced by providing opportunities and flexibility for importing green technologies with the support of defined rules and regulations for protecting environment. The results of this paper support the findings of Copeland and Taylor (2004), who supported trade for the betterment of environmental protection. The APEC countries can strengthen ties with the international community of trade partners to reduce poverty, increase the number of new job openings, and enhance imports and exports. By implementing these types of policies, global trade partners will see the value of trading with APEC countries.

Regarding the linkages of financial development with CO_2 emissions, a 1 percent increase in financial development improves the environmental quality by 0.0021 percent. These figures suggest that financial development helps to mitigate carbon emissions. The negative coefficient for this variable confirms that the financial sectors in the APEC economies allocate financial resources to environmental protection and support organizations and production units that use green technologies. Tamazian et al. (2009) contended that liberalization and financial openness attract research and development projects, as well as foreign investment. The resulting financial obligations and expenditures are primary sources of technologies that increase energy-related effectiveness and play an essential role in lowering carbon emissions. Likewise, Blanford (2009) argued that research and development is the best source of improvements in environmentally friendly technologies and decreased carbon emissions. On the contrary, financial development is not proved useful for environmental quality in countries where financial sector is at early stages, for instance, Haseeb et al. (2018) argued such for BRICS, Abbasi and Riaz (2016) for Pakistan, and Xiong et al. (2017) argued in the case of developing regions of China.

Providing sufficient opportunities for the private sector for production, commercialization, and investments can reduce poverty and boost developmental progress in APEC countries. The negative and deleterious relationship indicates a positive contribution of financial development in ecological degradation. Policymakers should allocate budget to environmental and energy-efficient projects. While there is a need for financial institutions to plan green investments considering environmental concerns. Institutions that are directly involved in the financial development process play a vital role in initiating environmentally friendly activities and reducing poisonous emissions in the atmosphere by means of the projects in which they choose to invest.

The positive and negative values of the coefficients for economic growth and GDP^2 square in relation to carbon emissions express the concept of EKC. When economic growth accelerates by 1%, CO_2 emissions also accelerate by 1.1209 percent, while 1 percent rise in GDP^2 decreases CO_2 emissions by 0.0069 percent. These relationships suggest that in early stages, increased economic growth in APEC countries also stimulate CO_2 emissions to a specific point but after that limit, CO_2 emissions start declining with the further increase in economic growth. These results support the EKC hypothesis in the APEC region. In the beginning stages of economic growth, countries are primarily concerned with economic expansion, and they ignore the environment, focusing on increasing trade with other countries and infrastructure development through globalization and financial development. Investments increase and people's income rises, thus energy demand increases and environmental degradation rises. Eventually, however, the rise in income level brings social and environmental awareness that helps to reduce environmental pollution (Zaidi et al., 2018). In this stage, economy is further boosted when more FDI comes in, with minimum damage to environment. These EKC effects evolve because of large-scale production with improved technologies and demands for environmental quality from citizens. These results match with those of Dogan (2016) for the US, Shahbaz et al. (2016c) for African economies, Danish et al. (2017) for Pakistan, (Shahbaz et al. (2017a,b,c) for China, and Sinha and Shahbaz (2018) for India.

There is also a significant positive relationship between energy intensity and CO_2 emissions, as a 1 percent rise in energy intensity leads to a 0.9768 percent rise in CO_2 emissions in APEC countries. Energy intensity represents energy consumption. When foreign firms come in, employment opportunities for local residents increase and the demand for energy rises. At these initial stages, increased use of fossils fuels increase environmental pollution, but at later stages, when these foreign firms have matured, they invest in energy-efficient infrastructure to reduce per unit costs, thereby decreasing their energy intensity such that environmental pollution also declines. Our findings suggest that energy use is the central cause of CO_2 acceleration. APEC authorities must plan to shift their energy consumption to renewable sources in order to attain emissions-free growth. Investigation of product life cycle is a helpful tool in determining energy intensity of products (Sabzevari et al., 2015). Furthermore, energy efficient requires innovative modeling to estimate optimization of energy demand and the potential reductions in GHGs (Qasemi-Kordkheili and Nabavi-Pelesaraei, 2014). We support Shahbaz et al.'s (2016c) conclusion concerning African countries and endorse the arguments of Nabavi-Pelesaraei et al. (2014) and Budzianowski (2012) that conventional energy can improve efficiency rapidly but is harmful to environment because it raises the level of carbon emissions.

The role of energy intensity in CO_2 emissions is a challenge to policymakers and a motivation for them to implement strategies regarding renewable sources of energy like solar, biodiesel, thermal, and wind and environmentally friendly technologies to reduce CO_2 emissions. Significant attention of government is required on resources management to control excessive use of fossil fuels in every sector of economy (Nabavi-Pelesaraei et al., 2016). APEC countries should import environmentally friendly products and consume less energy. Using the theory of comparative advantage, these countries should outsource the production of items that are highly energy intensive. These countries should also attract more FDI to strengthen financial development and import modern technology to increase energy efficiency. These countries should also increase intergovernmental cooperation for sustainable development and reform their institutional structures to sustain the positive effects of globalization and financial development.

4.2. panel granger causality analysis

CUP-BC and CUP-FM depict long-run linkages among the variables we considered, but these tests do not propose the path of causal linkages. Knowing the paths of these relationships is necessary to recommend sound policies. Due to occurrence of cross-sectional dependence among the variables, we can use traditional casualty methods to determine the causal relationship (Bhattacharya et al., 2016), including Dumitrescu and Hurlin (2012) causality test. Unlike other panel causality tests, this test considers heterogeneity in the time series panel data and runs separate regressions for every cross-section dataset to find causality. Moreover, two statistics are used to examine the significance of the causality: W-bar statistics, which uses average statistics for the test, and Z-bar information, which show a standard normal distribution. The results of Dumitrescu and Hurlin (2012) causality test are reproduced in Table-7.

The results reveal bidirectional causality between financial development and CO_2 emissions. Carbon emissions are Granger caused by globalization, economic growth and economic growth squared (GDP^2) in a one-way path. The results also suggest unidirectional causality running from GDP^2 to energy intensity, financial development to energy intensity and from globalization to energy intensity, thus supporting the conservative hypothesis for APEC countries. Furthermore, the results of Granger causality reflect that financial development impacts the GDP, whereas globalization causes financial development in Granger sense.

5. Conclusion

This empirical study seeks to determine the dynamic linkages between globalization, financial development and carbon emissions in the presence of energy intensity and economic growth for the APEC countries using panel data from 1990 to 2016. This study employs an updated methodology to test the links between the variables. We apply a cross-sectional approach to examine cross-sectional dependence among the variables. The variables' stationary properties are examined using CIPS and CADF tests of unit root, and long-run equilibrium is examined through Westerlund (2007) panel error correction cointegration approach. The long-run output elasticities are calculated using the CUP-FM and CUP-BC methods.

The results of Westerlund panel cointegration confirm a long-run equilibrium association between the underlying variables. The results of CUP-FM and CUP-BC techniques indicate that globalization significantly reduces CO_2 emissions and energy intensity in APEC countries, financial development leads to reduce CO_2 emissions, but economic growth and energy intensity boost the CO_2 emissions. The Dumitrescu and Hurlin causality analysis report bidirectional causality between financial development and CO_2 emissions. Carbon emissions are Granger caused by globalization, economic growth and economic growth squared (GDP^2) in a one-way path.

This results report the existence of EKC hypothesis in the APEC region, as when economies continue to grow and cross a specific output level, the demand for high-quality environment increases. Keeping the output level constant, countries then use modern technology to reduce CO_2 emissions. In such conditions, globalization helps to control environmental degradation and increase economic growth.

Clean energy and energy-efficient technology are long-term projects that require financing. Strong financial institutions and financial development structures are helpful in the development of such projects, which reduce energy consumption and CO_2 emissions.

This study has the limitation that some APEC countries are excluded from the panel set because of incomplete or missing data. In addition, we did not divide the APEC countries according to their income levels to check the impact of technology imports on the central relationship. Future studies could include income levels and technology imports to investigations of the central relationship in APEC countries.

Declarations of interest

None.

Acknowledgment

This study is sponsored by The National Natural Science Foundation of China [No.71571019].

Appendix

Table 2
Descriptive statistics and correlation matrix.

	$LNCO_2$	LNGL	LNFD	LNGDP	GDPS	LNEI
Mean	1.589373	4.09414	4.162374	9.140178	85.16467	4.863406
Median	1.858591	4.101792	4.432764	9.112877	83.04453	4.817605
Maximum	3.203038	4.4842	5.399467	10.90402	118.8975	6.219563
Minimum	−1.15909	3.110542	2.068356	6.100829	37.22012	4.030747
Std. Dev.	1.044787	0.247429	0.800307	1.275007	22.89274	0.379248
Probability						
$LNCO_2$	1					
	———					
LNGLOB	0.695643	1				
	0	———				
LNFD	0.504264	0.476644	1			
	0	0	———			
LNGDP	0.890176	0.754387	0.512065	1		
	0	0	0	———		
GDPS	0.882415	0.73575	0.522125	0.997793	1	
	0	0	0	0	———	
LNEI	0.268488	−0.11541	0.101517	−0.084114	−0.07809	1
	0	0.0173	0.0364	0.0833	0.1079	———

Table 3
Cross-sectional dependence test results.
Note: ***, show rejection level of null hypothesis at 1%. Cross-sectional dependence (CD) test is distributed under the standard norm of two-tailed.

Variables	CD-test Pesaran (2004)	Corr
$\ln CO_2$	14.38 ***	0.247
lnGLOB	52.60 ***	0.902
lnFD	43.01 ***	0.218
lnGDP	42.98***	0.737
lnGDPS	31.66***	0.735
lnEI	21.12***	0.362

Table 4
Unit root tests results.

variables	CIPS		CADF	
	Level	First difference	Level	First difference
$\ln CO_2$	−1.937	−4.244 ***	−2.071	−3.170***
lnGLOB	−2.481	−5.150 ***	−2.316	−3.590***
lnFD	−1.954	−3.910 ***	−2.322	- −3.041***
lnGDP	−2.178	−3.505 ***	−2.295	−2.921***
lnGDPS	−2.164	−3.454 ***	−2.382	−2.969***
lnEI	−1.877	−4.086 ***	−1.897	−3.129 ***

Note: Here CIPS of truncated test is used. *** show the rejection of null hypothesis. We included a Constant and Trend as suggested by Pesaran (2007). We reject the null hypothesis if data of atleast one country is stationary. Critical values of CIPS for 1% significance level is (−2.81) and for CADF (−2.58) for 1% significance level.

Table 5
Westerlund panel cointegration test results.

Statistics	Value	Z-value	P-value	Robust P-value
Gt	−2.309**	−1.325	0.092	0.029
Ga	−7.044*	1.644	0.950	0.098
Pt	−9.573*	−2.294	0.011	0.070
Pa	−7.310	−0.675	0.250	0.100

Note: ***, ** and * show significance at the 1%, 5% and 10% levels, respectively. This technique does not take any cointegration as null. We used constant and constant with trend taking one lag and one lead. The width of the Bartlett kernel, window is used in the semi-parametric estimation of long run variances. P-values are calculated on the basis of normal distribution for a one-sided test.

Table 6
Long-run estimation results.

Variables	CUP-FM		CUP-BC		PMG	
	coefficient	t-statistics	coefficient	t-statistics	coefficient	t-statistics
lnGLOB	−0.0330**	2.5503	−0.0627***	3.0749	−0.086***	3.464
lnFD	−0.0021***	7.48577	−0.0089***	7.92114	−0.028**	−2.298
lnGDP	1.1209***	8.3359	1.1015***	8.4417	1.523***	4.899
lnGDPS	−0.0069***	15.4065	−0.0063***	15.8410	−0.029*	1.741
lnEI	0.9768***	24.1376	0.8901***	21.8802	0.968***	20.063

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

Table 7
Dumitrescu and Hurlin (2012) heterogeneous panel causality test results.

Dependent	Independent					
	$\ln CO_2$	lnEI	lnGDP	lnGDPS	lnFD	lnGLOB
$\ln CO_2$		3.1723*** (0.0015)	3.4007*** (0.0007)	3.4404*** (0.0006)	2.5663** (0.0103)	1.0903 (0.2756)
lnEI	2.6343*** (0.0084)		3.6192*** (0.0003)	3.5479*** (0.0004)	1.9890** (0.0467)	3.3727*** (0.0007)
lnGDP	0.6263 (0.5311)	1.3958 (0.1628)		1.0207 (0.3074)	10.3250*** (0.0000)	0.9162 (0.3595)
lnGDPS	0.4913 (0.6232)	1.3675 (0.1714)	1.0175 (0.3089)		10.5353*** (0.0000)	0.89449 (0.3711)
lnFD	3.8097*** (0.0001)	1.0801 (0.2801)	0.4318 (0.6658)	0.4493 (0.6532)		2.8832 (0.0039)
lnGLOB	0.4517 (0.6514)	1.0235 (0.3061)	1.3665 (0.1718)	1.3706 (0.1705)	0.43819 (0.6612)	

Note: ***, ** and * show significance at the 1%, 5% and 10% levels, respectively. We used Schwarz information criterion (SC) to select appropriate lag length.

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