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The impacts of different proxies for financialization on carbon emissions in top-ten emitter countries

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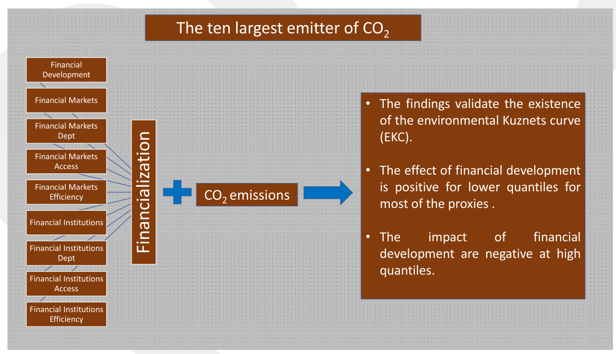
HIGHLIGHTS

- The impact of financializaton on carbon emissions is studied for top emitters.
- Nine different indices are used as a proxy for financializaton.
- Financialization increases carbon emissions at low quantiles for five proxies.
- Financialization has an adverse impact on the pollution over high quantiles for all proxies.
- The EKC hypothesis is validated for the sample countries.

GRAPHICAL ABSTRACT



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ABSTRACT

The nexus of financialization and carbon emissions has been widely discussed in the literature. A vast body of literature that estimates the impact of financialization on carbon emissions proxies financialization with either domestic credit or market capitalization. However, these representatives do not fully respond to the complicated nature of financial development. To fill the gaps in the existing literature, nine different proxies for financial development are used in the links with carbon emissions in the framework of EKC theory for the years 1980–2014. This study exposes reliable and robust empirical results due to the use of a number of proxies for financialization and second-generation econometric approaches in the empirical analysis. The quantile regression approach deals with unobserved heterogeneity for each cross-section and estimates different slope parameters at varying quantiles. Because non-normality and heterogeneity are detected in dataset, quantile regression provides more robust and reliable estimates than conventional econometric techniques. Results from quantile regression estimator support mixed effects of financial development on carbon emissions over quantiles; in addition, the impact of financial development on carbon emissions is varying not only for each quantile but also for different proxies of financial development. The EKC hypothesis is validated for the top-ten emitter economies. Interpretations and policy suggestions are further discussed in the present study.

1. Introduction

Over the past two decades, environmental changes have become a global challenge that has attracted the attention of environmental researchers, policymakers and worldwide organizations. The global warming and the climate changes occur due to increasing polluting

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energy sources that adversely affect the health of human beings (Adedoyin et al., 2020; Mardani et al., 2019; Zhang et al., 2018). Such an overwhelming rise in worldwide temperature and its adverse effects on the environment caused the establishment of the United Nations Framework Convention on Climate Change in 1992. Later, the Kyoto Protocol in 1997 and the Paris Contract in 2015 were developed to mitigate global warming by restricting gas emissions. Over the years, environmental degradation arises from greenhouse gases has become an important issue in the worldwide environmental debate (Seetanah et al., 2018). Carbon dioxide (CO_2) emissions account for around 75% of greenhouse gas emissions (Abbasi and Riaz, 2016). In addition, CO_2 emission was 1.2% during 2016–17 but increased to 1.9% in 2018, which is considered pretty high (EDGAR, 2019). The U.N. Intergovernmental Panel on Climate Change reports that the worldwide temperature increased to 1.5 °C, which is indeed quite high. Thus, prompt actions are required to decrease CO_2 emissions from major pollutant countries. Indeed, the world's top-ten CO_2 emitters (Brazil, Canada, China, India, Iran, Japan, Korea, Saudi Arabia, the United States and South Africa) account for nearly two-third of the total emissions. According to the BP Statistical Review of World Energy 2019, the top emitter countries contribute significantly to the total CO_2 emissions; for instance, China (27.8%), USA (15.2%), India (7.3%), Japan (3.4%), South Korea (2.1%), Iran (1.9%), Saudi Arabia (1.7%), Canada (1.6%), Brazil (1.3%) and South Africa (1.2%), which demonstrates that they are important players for reducing the amount of emissions in the world. Moreover, the top emitter countries together account for around 51% of the global population, 65% of worldwide gross domestic product, 80% of total international fossil fuel consumption and 67.5% of total worldwide fossil CO_2 (WDI, 2020).

The previous studies have extensively focused on the environment-growth nexus (Stern, 2004; Fodha and Zaghdoud, 2010; Omri, 2014; Churchill and Ivanovski, 2020), the validity of the environmental Kuznets curve (EKC) hypothesis to investigate the relationship between economic growth and environmental quality (Shahbaz et al., 2012; Al-Mulali et al., 2015a, 2015b; Alam et al., 2016; Kwakwa and Adu, 2016; Aboagye, 2017; Dong et al., 2018; Sinha and Shahbaz, 2018), and the growth-energy-environment nexus (Sarkodie et al., 2019; Mardani et al., 2019; Dogan et al., 2020). Some empirical studies (Bekhet et al., 2017; Gokmenoglu and Sadeghieh, 2019; Wang et al., 2019; Shahbaz et al., 2020) introduce financial development as an important explanatory variable to show that financial development may determine the changes in carbon emissions.

Different schools of thought have different views on the relationship between financial development and carbon emissions. One school of thought argue that financial development increases environmental deterioration (Brännlund et al., 2007; Sadorsky, 2010, 2011; Coban and Topcu, 2013; Islam et al., 2013; Tang and Tan, 2014; Wang et al., 2019). An established financial system not only contributes to improve the performance and efficacy of the financial sector but also leads to economic growth and development in a country (Tamazian et al., 2009; Sadorsky, 2010; Zhang, 2011; Shoaib et al., 2020). The development of stock and financial markets causes lowering finance expenditures, alleviating liquidity restriction for firms, thereby investing in new projects to expand production, increasing energy demand and thus the pollution (Dasgupta et al., 2001; Ma and Fu, 2020). Moreover, financialization accelerates economic growth and carbon emissions through foreign direct investment inflows (Frankel and Romer, 1999). According to Sadorsky (2010), financial intermediation motivates people to take loan to purchase heavy vehicles that cause to increase emissions. On the contrary, few researchers deny above arguments and find that financial development leads to mitigate environmental degradation by utilizing energy-efficient technologies (King and Levine, 1993; Tadesse, 2005; Tamazian and Bhaskara Rao, 2010; Jalil and Feridun, 2011; Zhang, 2011; Shahbaz et al., 2013b, 2016; Shahzad et al., 2014; Chang, 2015; Shahbaz et al., 2016; Pata, 2018).

The first motivation of the present study is thus to introduce nine financial development proxies of the IMF so as to better understand the way of impact of financialization on carbon emissions. A vast body of existing empirical studies uses a simple and single proxy for financial development. For instance, studies by proxying financialization with domestic credit to private sector find that it has a positive effect on the environment degradation; such as, Al-Mulali et al. (2015a, 2015b) for Europe; Ahmed (2017) and Haseeb et al. (2018) for BRIC countries, Ali et al. (2019) for Nigeria; Ahmad et al. (2019) for China, Kayani et al. (2020) for emitter countries. On the other hand, studies which employ the same proxy reveal that financialization adversely impacts the pollution; such as, Jalil and Feridun (2011) for China, Shahbaz et al. (2013a) for South Africa, Shahbaz et al. (2013c) for Malaysia, Samia and Nasreen and Anwar (2015) for low- middle- and high-income countries, Lee et al. (2015) for OECD, Abbasi and Riaz (2016) for Pakistan, Dogan and Seker (2016) for top renewable energy countries, Gill et al. (2019) for Malaysia. By using same proxy (domestic credit), few researchers find insignificant nexus of environment and financialization; such as, Ozturk and Acaravci (2013) for Turkey, Seetanah et al. (2018) for Small Island Developing States.

A couple of researchers uses an additional simple proxy, domestic credit provided by financial sector, to explore its effect on carbon emissions (Ziaei, 2015 for European countries, East Asian and Oceania countries; Ali et al., 2019 for Nigeria; Jiang and Ma, 2019a, 2019b for developed, emerging and developing countries). Moreover, a few recent studies use several proxies for robustness. For instance, Tsaurai (2019) extends his analysis by using three different proxies of financial development (domestic credit to financial sector; domestic credit to private sector by banks, and broad money) for Africa. Katircioğlu and Taşpinar (2017a, 2017b) employs four different proxies (domestic credits to the banking and private sector, broad money supply, ratio of commercial bank assets to central bank assets plus commercial bank assets, liquid liabilities, and exposes an inverse relationship between financial development and CO_2 emissions in Turkey. Shoaib et al. (2020) employs five different proxies (domestic credit to private sector, stock market capitalization, stock market turnover ratio, bank net interest margin, and bank z-score for developing countries and developed countries, and explores a positive relationship between financialization and the level of emissions.

The above-listed recent studies of literature that use more than one simple proxy for financial development is a bonus motivation because these indicators of financialization may not fully and efficiently respond to the complicated nature of financialization (IMF, 2020). As over the years, financial sectors have developed across the world and now become multi-dimensional. Financial sector (markets and institutions) helps in monitoring investment activities and managerial performance of the corporations. The key role of financial sector is to bring debtor and lender together with the intention of allocation of capital for most profitable purpose. Financial markets and financial institutions play a considerable role in order to promote economic development and economic stability in a country (Levine, 2005). For instance, financial institutions (particularly banks) and securities markets utilize household's savings for investment purposes; lead to promote economic development in a country. In order to overcome the limitation of single proxy of financial development, our study fills this gap by employing nine different indices of financial development (IMF, 2020), thus according to our knowledge, this is the first study that extends the literature by utilizing nine different indices. These indices summarize the state of financial markets and institution in terms of depth (size and liquidity), access (ability of enterprises to obtain financial services), and efficiency (ability of institutes to deliver their financial services at lower cost and with sustainable returns). The financial institution, for instance, banking sector (investment banks, pension and mutual funds, insurance companies) and non-banking sector paly a substantive role in an economy. On the same way, through financial markets enterprises and individuals can diversify their savings, and businesses can increase capital through wholesale money markets, bonds and stocks. Such financial markets and institutions promote the financial services (Aizenman et al., 2015; Čihák et al., 2012). The diversity of financial structure suggests multiple indicators to measure financial development across countries.

The second motivation of the present study is to use up-to-date econometric techniques in empirical analysis. Even though some studies start taking into account cross-sectional dependence and heterogeneity to analyze the nexus of financialization and environment (Ahmed, 2017; Ehigiamusoe and Lean, 2019), the existing studies mostly employ conventional panel estimation methods; such as, vector error correction and vector autoregressive approach (Shahzad et al., 2014; Shahbaz et al., 2013a; Shahbaz et al., 2013b., Shahbaz et al., 2013c; Ozturk and Acaravci, 2013; Jalil and Feridun, 2011; Tamazian et al., 2009; Gokmenoglu and Sadeghieh, 2019; Kayani et al., 2020; Tamazian et al., 2009; Zhang, 2011; Bekhet et al., 2017; Cetin et al., 2018; Dogan and Turkekul, 2016; Ali et al., 2019; Seetanah et al., 2018), generalized method of moments (Tamazian and Bhaskara Rao, 2010; Sadorsky, 2010; Jiang and Ma, 2019a, 2019b; Saidi and Ben Mbarek, 2017; Ma and Fu, 2020); Pedroni panel cointegration (Al-mulali and Lee, 2013); Ahmed, 2017; Ziaei, 2015); ordinary least squares (OLS), fully-modified OLS, and dynamic OLS (Tsaurai, 2018; Shahzad et al., 2014; Dogan and Seker, 2016; Nasreen and Anwar, 2015; Al-Mulali et al., 2015a, 2015b; Tsaurai, 2020). In line of the second motivation, our study contributes to the literature by employing a panel quantile regression.

In the last years, quantile regression has become a core research subject and has been extensively used in the environment literature (Ike et al., 2020; Sharif et al., 2020; Huang et al., 2020). The motivation behind utilizing the panel quantile regression model is fourfold. Firstly, unlike conventional regression analysis that only calculates the average effect of covariate on explained variable, thus quantile regression is employed in order to avoid over and under estimation of dependent and independent variables (Zhu et al., 2016). Second, this approach explains the entire conditional distribution of the explained variable (carbon emissions in this study), thus helps to have clear understanding of the factors that cause carbon emissions. From a policy perspective, it is pretty interesting to identify what happens at the extremes of distribution. On the contrary, OLS is not an ideal method for formulating climate protection policies for high emitter countries. Third, this approach deals with unobserved heterogeneity for each cross-sectional and estimates different slope parameters at varying quantiles (Uddin et al., 2017). Fourth, panel quantile regression results are more efficient and stronger than traditional OLS because results are robust in order to outlying observations of a dependent variable particularly when the error term is not normal (Alsayed et al., 2020). Thus, we believe that policymakers able to implement more effective policies to safeguard the environment because the use of quantile regression technique is beyond conventional estimation methods (Chang et al., 2020).

In light of the above motivations and discussions, the aim of the present study is to investigate the impact of financialization, energy consumption and economic growth on carbon emissions for the top-ten emitter countries over the years 1980–2014 by using second-generation econometric approaches. As far as we are aware, this paper is the first attempt in the literature to study the effect of financialization by using nine different proxies on CO_2 emissions. The use of several proxies should help researchers and policymakers to better understand the environmental consequences of financial development in countries.

The remainder of the study is as follows. Section 2 defines the model, data and the methods; Section 3 explores empirical results and discussions; Section 4 presents conclusion of the study and policy implications.

2. Model, data and methodology

2.1. Model and data

This study is based on a widely-adopted Environmental Kuznets Curve (EKC) model, which basically tests the pollution-income nexus popularized by Grossman and Krueger (1995). In the years since the original empirical work was proposed, researchers have used CO_2 emissions as a proxy for environmental pollution and have added energy consumption and financial development into the original model for evidence of the EKC hypothesis (Katircioğlu and Taşpinar, 2017a, 2017b; Gill et al., 2019). Inspired by the mentioned works, this study uses the following model:

$$\text{Model}: \text{CO2}_{\text{it}} = f\left(\text{GDP}_{\text{it}}, \text{GDP}^2{}_{\text{it}}, \text{EGY}_{\text{it}}, \text{FD}_{\text{it}}\right)$$

where CO_2 is carbon dioxide emissions (kt) per capita; GDP is the real gross domestic product per capita in constant 2010 $; EGY is energy consumption measured by kg of oil equivalent per capita. This study uses nine different financialization indices of the financial development (FD) by the International Monetary Fund and nine different models, accordingly. These are financial development index (FDI), financial institutional index (FII), financial markets index (FMI), financial institutions depth index (FIDI), financial institutions access index (FIAI), financial institutions efficiency index (FIEI), financial markets depth index (FMDI), financial markets access index (FMAI) and financial markets efficiency index (FMEI), respectively. The expected sign of coefficients on GDP and GDP^2 will be positive and negative if the EKC hypothesis is valid for countries. The expected sign of the coefficient of energy consumption is positive. However, the effect of financialization on pollution is ambiguous.

This study covers the top-ten emitters of CO_2 emissions: Brazil, Canada, China, India, Iran, Japan, the Republic of Korea, Saudi Arabia, the United States of America and South Africa. The annual data from 1980 to 2014 are taken from the World Development Indicators (https://data.worldbank.org/) and the IMF database (https://data.imf.org/). It should hereby worth noting that this study employs the largest time period of countries for the analyzed variables. The natural logarithm of the dataset is used in the empirical analysis.

2.2. Methodology

A large body of literature suggests that working on panel data sets likely to have the issue of cross-section dependence. This problem arises due to different global and local common shocks and unobserved components. These unobserved components have mainly become a part of the error term. The rising trend in cross-section dependence is associated with rising financial and economic integration through increasing international trade. The issue of cross-section dependence also depends upon correlation among cross-sectional units (De Hoyos and Sarafidis, 2006). However, ignoring this issue may provide inefficient and unreliable estimator results. Therefore, this study starts with testing the presence of cross-section dependence to get efficient results. For this purpose, Pesaran (2004a, 2004b) cross-section (CD) dependence test is used. The general form of Pesaran (2004a, 2004b) CD test is given as:

$$CD_{Pesaran-2004} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho_{it}}\right) \quad (1)$$

The null hypothesis for CD test support independence of cross-sectional units. CD test has zero mean and constant variance, i.e., 1 in case of large T and $N\rightarrow\infty$ (Pesaran, 2004a, 2004b). The zero mean and constant variance is followed for panel data sets having non-stationary, dynamic, and heterogeneous panel models. Along with cross-section dependence, this study uses the slope homogeneity test proposed by Pesaran and Yamagata (2008). This approach provides two important statistics, i.e., $\tilde{\Delta}$ and adjusted $\tilde{\Delta}$ with a null hypothesis of homogenous slope and heterogeneous in case of the alternative hypothesis. For unit root testing, this study uses two different unit root tests, i.e., Im et al., 2003a, 2003b and Cross-sectionally augmented Im, Pesaran and Shin (CIPS) (Pesaran, 2007). These tests have different assumptions and power to tackle various issues in panel data sets. Im et al., 2003a, 2003b test statistics can be written as:

$$\Delta Y_{i,t} = \gamma_i Y_{i,t-1} + \sum_{j=1}^{P_i} \delta_{i,t} Y_{i,t-j} + Z'_{i,t}\theta + \mu_{i,t} \quad (2)$$

Here in Eq. (2), $i = 1, \ldots\ldots. N$ is for cross-sections and t for the time period starting from $t = 1, \ldots\ldots. T$. The $\Delta Y_{i,\,t}$ is for the first difference which is $\Delta Y_{i,\,t} = Y_{i,\,t} - Y_{i,\,t-1}$and p is for the number of lags. Moreover, the error term is assumed to have constant variance with zero mean. Im et al., 2003a, 2003b allows γ_i to vary for each cross-section, i.e., heterogeneous.

This study employs another panel unit root test developed by Pesaran (2007) termed it as cross-sectionally augmented Im, Pesaran and Shin (CIPS). This method not only tackles the problem of heterogeneity but also overcome the issue of cross-section dependence. The baseline equational form for CIPS is given as:

$$\Delta y_{i,t} = \varnothing_i + \varnothing_i W_{i,t-1} + \varnothing_i \overline{X}_{t-1} + \sum_{l=0}^{p} \varnothing_{il} \Delta\overline{X_{t-l}} + \sum_{l=1}^{p} \varnothing_{il} \Delta X_{i,t-l} + \mu_{it} \quad (3)$$

The average values for each cross-section and lags are given in Eq. (3) are denoted by $\overline{X}_{t-1}$ and $\Delta\overline{X_{t-l}}$. Before using quantile regression analysis, cointegration tests such as Pedroni (1999), Westerlund (2005) and Westerlund (2007) are employed. Pedroni (1999) and Westerlund (2005) take into account slope heterogeneity effectively, while Westerlund (2007) can be used in the case of both cross-section interdependence and slope heterogeneity.

The null hypothesis for all three tests suggests no cointegration. Moreover, to obtain empirical results, this study uses quantile regression analysis suggested by (Koenker and Bassett Jr, 1978). Unlike conventional regression analysis, which only estimates the average effect of covariates on dependent variables, which may cause over and underestimation of coefficients. Therefore, this approach is used as it avoids the over and under-estimation of coefficients and also captures all-important associations between dependent and independent variables (Zhu et al., 2016). First, it provides a different effect of independent variables on the dependent variable due to varying quantiles. Second, it follows a non-parametric specification or non-normality assumption. Third, it deals with unobserved heterogeneity for each cross-section and estimates different slope parameters at varying quantiles. It helps to provide efficient estimations and is robust to outliers (Zhu et al., 2016; Chamberlain, 1994; Uddin et al., 2017). The general quantile conditional function for quantile τ is given as:

$$Q_{CO_{2,it}}(\tau|\gamma_i, \delta_t, X_{i,t}) = \gamma_i + \delta_t + \alpha_{1,\tau} GDP_{i,t} + \alpha_{2,\tau} GDP_{i,t}^2 + \alpha_{3,\tau} EN_{i,t} + \alpha_{4,\tau} FD_{i,t} + \mu_{\tau,i,t} \quad (4)$$

where τ show quantiles such as 25th, 50th and 75th, $i = 1, \ldots\ldots. N$ is for cross-sections and t for the time-period starting from $t = 1, \ldots\ldots. T$, CO_2 is the dependent variable. Equations for each quantile is given as:

$$Q_{0.25}(CO_2) = \gamma_{0.25} + \alpha_{1,0.25} GDP_{i,t} + \alpha_{2,0.25} GDP_{i,t}^2 + \alpha_{3,0.25} EN_{i,t} + \alpha_{4,0.25} FD_{i,t} + \mu_{0.25,i,t} \quad (5)$$

$$Q_{0.50}(CO_2) = \gamma_{0.50} + \alpha_{1,0.50} GDP_{i,t} + \alpha_{2,0.50} GDP_{i,t}^2 + \alpha_{3,0.50} EN_{i,t} + \alpha_{4,0.50} FD_{i,t} + \mu_{0.50,i,t} \quad (6)$$

$$Q_{0.75}(CO_2) = \gamma_{0.75} + \alpha_{1,0.75} GDP_{i,t} + \alpha_{2,0.75} GDP_{i,t}^2 + \alpha_{3,0.75} EN_{i,t} + \alpha_{4,0.75} FD_{i,t} + \mu_{0.75,i,t} \quad (7)$$

The econometric methodology mentioned above is implemented by first testing for normality of the data, stationary of the dataset and slope heterogeneity. Following the outcome of non-normality, non-stationarity and heterogeneity, this study uses panel quantile regressions accordingly. Further, empirical estimations are obtained using Stata/Eviews/R software.

3. Empirical results and discussions

The summary statistics and normality tests are reported in Table 1. The summary statistics provide minimum and maximum values for all the variables along with the mean and median values. Moreover, the probability value of skewness, kurtosis and Jarque-Bera (JB) test are also given in Table 1. The normality of data is tested by using skewness, kurtosis and JB test. The first one is the measure of asymmetry, the second one is about the sharpness and height of the peak of the curve, and the last one is a goodness-of-fit test of whether a dataset has the skewness and kurtosis matching a normal distribution. The normality assumption based on skewness and kurtosis requires to have near-zero mean and mesokurtic. The statistically significant results of skewness, kurtosis and JB indicate that the dataset is asymmetrically distributed in the panel of top-emitter countries. The results for the normality test reject the null hypothesis of normality and suggest that all the variables are non-normally distributed. The presence of the non-normality of the analyzed data further suggests the use of the quantile regression approach.

Since quantile regression analysis is robust to heterogeneous panel data sets; therefore, we first checked whether the slope homogeneity hypothesis is valid or not. The slope homogeneity test results are reported in Table 2. The null hypothesis of the Pesaran and Yamagata (2008) test is rejected for all the nine models by using different proxies for financial development at a 1% significance level. These results provide reasonable support to uses quantile regression for further analysis. Similarly, these results also provide support to use Im, Pesaran and Shin (IPS) and cross-sectionally augmented IPS (CIPS) unit root test.

Results from the cross-sectional (CD) test proposed by Pesaran (2004a, 2004b), and IPS and CIPS unit root tests are reported in Table 3. The cross-section dependence test rejects the null hypothesis of no cross-sectional dependence for all cross-sections at 1% significance level. In the modern era, with a rising trend in globalization, capital mobility, economic integration, common shocks, i.e., global financial crises, oil prices shocks, gold prices shock etc. as complete independence is almost impossible. The sampled countries in this study contribute significantly not only to the global economic growth but also add a significant portion to international trade. The evidence of strong interdependence in these countries is due to increasing international trade, financial and economic integration.

Similarly, unit root properties for each series is performed by employing CIPS and IPS approaches. The results from IPS indicate the rejection of null hypothesis for all the variables such as CO_2, GDP, GDP^2, EGY, FDI, FII, FMI, FIDI, FIAI, FIEI, FMDI, FMAI and FMEI is rejected only

Table 1
Descriptive statistics and normality tests.

Var.	Obs#	Min	Max	Mean	Median	Pr (Skewness)	Pr (Kurtosis)	Pr (JB test)
CO2	350	−0.80	3.03	1.79	2.13	0.00	0.00	0.00
GDP	350	5.84	10.83	9.12	9.11	0.00	0.05	0.00
GDP^2	350	34.21	117.50	85.05	83.10	0.01	0.00	0.00
EGY	350	5.65	9.04	7.76	7.90	0.00	0.00	0.00
FDI	350	2.38	4.47	3.79	3.80	0.02	0.02	0.02
FII	350	2.85	4.51	3.92	3.92	0.02	0.00	0.00
FMI	350	1.39	4.53	3.54	3.62	0.00	0.04	0.00
FIDI	350	1.12	4.55	349.0	3.79	0.00	0.00	0.00
FIAI	350	1.46	4.53	3.53	3.78	0.00	0.00	0.00
FIEI	350	2.68	4.48	4.13	4.21	0.00	0.00	0.00
FMDI	350	−0.01	4.60	3.15	3.45	0.00	0.85	0.00
FMAI	350	1.38	4.56	3.20	3.23	0.05	0.00	0.01
FMEI	350	0.75	4.60	3.73	4.00	0.00	0.14	0.00

Table 2
Results of slope homogeneity test.

	Proxy: FDI	Proxy: FII	Proxy: FMI	Proxy: FIDI	Proxy: FIAI	Proxy: FIEI	Proxy: FMDI	Proxy: FMAI	Proxy: FMEI
Δ	23.84**	21.92**	23.27**	22.66**	23.40**	21.34**	22.61**	23.89**	22.82**
Δ_{adj}	25.76**	23.67**	25.13**	24.48**	25.27**	23.05**	24.42**	25.81**	24.64**

** Denotes the statistical significance at 1% level.

at the first difference (I(1)). However, the null hypothesis cannot be rejected for all variables at level (I(0)). To account for cross-section dependence and slope heterogeneity, CIPS test is employed. The results support the alternative hypothesis of stationarity of variables such as CO_2, GDP, GDP^2, EGY, FDI, FII, FMI, FIDI, FIAI, FIEI and FMDI at the first difference (I(1)) except for FMAI and FMEI which is stationary at level (I(0)). All the results for IPS and CIPS are significant at 1% level. The outcomes support the first difference sequence for the empirical results of this study.

The long-run cointegration relationship for all nine models are tested through Pedroni (1999), Westerlund (2005) and Westerlund (2007) cointegration approaches. The results verified long-run cointegration among carbon emissions, GDP, GDP^2, financial development (using nine different proxies) and energy consumption. The results are significant at the mixed significance level, i.e., 10%, 5% and 1%. These results reject the null hypothesis and accept the alternative of cointegration. The results from these tests are reported in Table 4.

Following Koenker (2004), this study applies quantile regression on the dataset. The empirical outcomes for all models using different proxies for financial development are reported in Table 4. All the results are estimated at 25th, 50th and 75th quantiles. This study estimated nine different models by using nine different proxies of financial development which include financial development index (FDI), financial institutional index (FII), financial markets index (FMI), financial institutions depth index (FIDI), financial institutions access index (FIAI), financial institutions efficiency index (FIEI), financial markets depth index (FMDI), financial markets access index (FMAI) and financial markets efficiency index (FMEI), respectively. For gross domestic product (GDP), the effect is positive on CO_2 for all nine proxies of financial development; however, different quantile levels have different coefficients.

For FDI, FII and FMI, the effect of GDP for 25th quantile is positive and statistically significant with 0.75%, 0.62% and 0.70% coefficient which reaches to 0.84%, 0.79% and 0.78% at 50th quantile with a decline at 75th quantile with a coefficient of for FDI is 0.77%, and FMI is 0.75%, while a rise for FII at 75th quantile with a coefficient of 0.84%, respectively. Moreover, FIDI, FIAI, FIEI, FMDI, FMAI and FMEI, 1% increase in GDP is positive on CO_2. At 25th, 50th and 75th quantile, the rise associated with GDP in CO_2 is 0.60%, 0.87% and 0.85% for FIDI, 0.73%, 0.84% and 0.95% for FIAI, 0.71%, 0.59% and 0.74% for FIEI, 0.75%, 0.86% and 0.88% for FMDI, 0.72%, 0.73% and 0.77% for FMAI, 0.63%, 0.45% and 0.73% for FMEI, respectively.

Similarly, the positive effect of GDP on CO_2 can also be verified from Fig. 1. For all nine models except for FMEI and FIEI, the figure clearly shows that the rise in CO_2 due to GDP is substantial and increases at a higher magnitude at 25th quantile; however, it falls again at 75th quantile. In the early stages of economic growth, the primary production increasing at a quick rate, in this stage waste accumulation increases along with depletion of natural resources. These results support the findings of Kaika and Zervas (2013), Ozokcu and Özdemir (2017), and Khan et al. (2020), which argue that rise in the economic activities cause a positive effect on carbon emissions.

In contrast, GDP^2 is negatively affecting CO_2 for all nine proxies of financial development. The coefficient for 25th, 50th and 75th quantile for all nine models are ranging from −0.03% to −0.06%. These findings are also confirmed by Fig. 1, especially following GDP^2 curve. Similarly, in some cases, there also exists an N-shaped environmental Kuznets curve (EKC), which can be verified from Fig. 1. The validity of EKC in these top emitter countries indicates that these countries have reached to a certain of level of economic growth and now moving towards environmental-friendly economic growth. The validity of inverted U-shaped confirms the findings of Lean and Smyth (2010), Aboagye (2017), Dong et al. (2018), Sinha and Shahbaz (2018). In addition, Kaika and Zervas (2013) argues that increasing economic growth causes to improve technology, promotion of alternative energy sources and relying on these renewable energy sources for production and expands tertiary and services sector which helped to contain carbon emissions.

In other words, these top-ten emitter countries have reached to a satiety point. These countries are now moving towards a cleaner production process that not only promotes high economic growth but also helped them to achieve lower carbon emissions. These empirical outcomes further indicate that all these sampled countries have passed through the scale effect and now entered into technique and composition effect. This means the deterioration caused by economic growth at the initial stage is now going towards more environmentally friendly

Table 3
Results of cross-sectional and unit-root tests.

Var.	CD-test	IPS		CIPS	
		Level	Diff.	Level	Diff.
CO2	8.95**	−1.86	−5.47**	−1.84	−5.06**
GDP	24.1**	−2.01	−4.67**	−2.44	−4.62**
GDP^2	24.2**	−1.87	−4.61**	−2.39	−4.56**
EGY	19.1**	−1.40	−5.71**	−1.39	−5.57**
FDI	29.1**	−2.14	−5.87**	−2.03	−5.41**
FII	20.7**	−2.21	−5.86**	−1.92	−5.60**
FMI	31.2**	−2.40	−5.94**	−2.42	−5.33**
FIDI	30.4**	−2.13	−5.32**	−1.84	−5.27**
FIAI	18.1**	−0.58	−5.18**	−1.62	−5.41**
FIEI	2.25**	−1.97	−6.04**	−1.94	−5.97**
FMDI	33.8**	−1.92	−6.61**	−2.58	−5.67**
FMAI	31.4**	−2.52	−5.84**	−2.93**	−5.27**
FMEI	11.3**	−1.85	−6.8**	−3.26**	−5.95**

** Denotes the statistical significance at 1% level.

Table 4
Results of panel cointegration tests.

	Proxy: FDI	Proxy: FII	Proxy: FMI	Proxy: FIDI	Proxy: FIAI	Proxy: FIEI	Proxy: FMDI	Proxy: FMAI	Proxy: FMEI
Pedroni (1999)	−2.95***	−2.87***	−2.73***	−3.62***	−2.65***	−2.01***	−2.59***	−3.02***	−2.70***
Westerlund (2005)	−2.03**	−1.91**	−1.99**	−2.10**	−1.83**	−1.17	−1.98**	−2.02**	−1.97**
Westerlund (2007)	−2.72**	−2.67**	−2.58**	−2.39*	−2.81***	−2.52**	−2.80***	−2.41*	−2.49*

*** Denotes the statistical significance at 1% level.
** Denotes the statistical significance at 5% level.
* Denotes the statistical significance at 10% level.

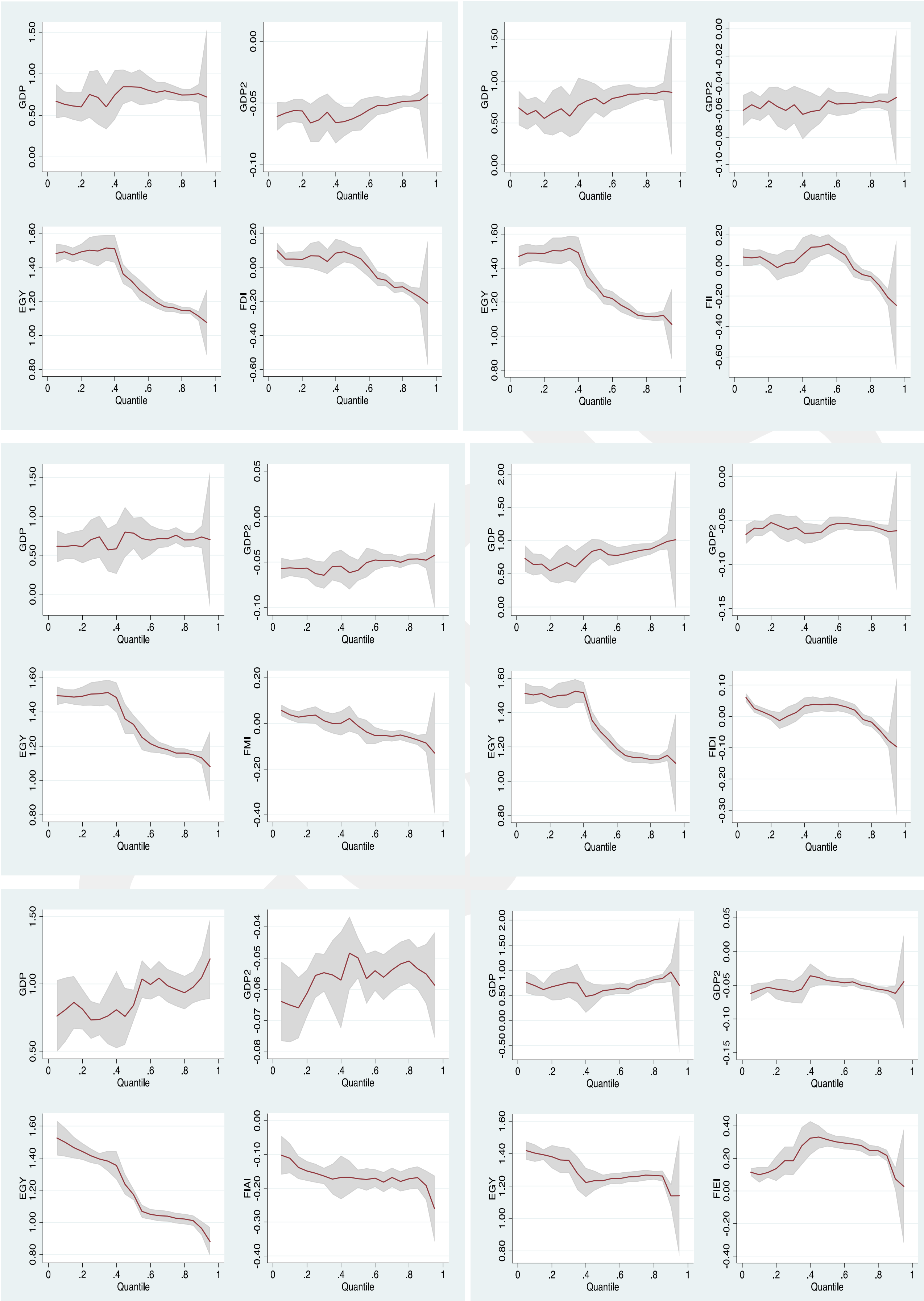

Fig. 1. Estimates of coefficients from quantile regressions for nine proxies.

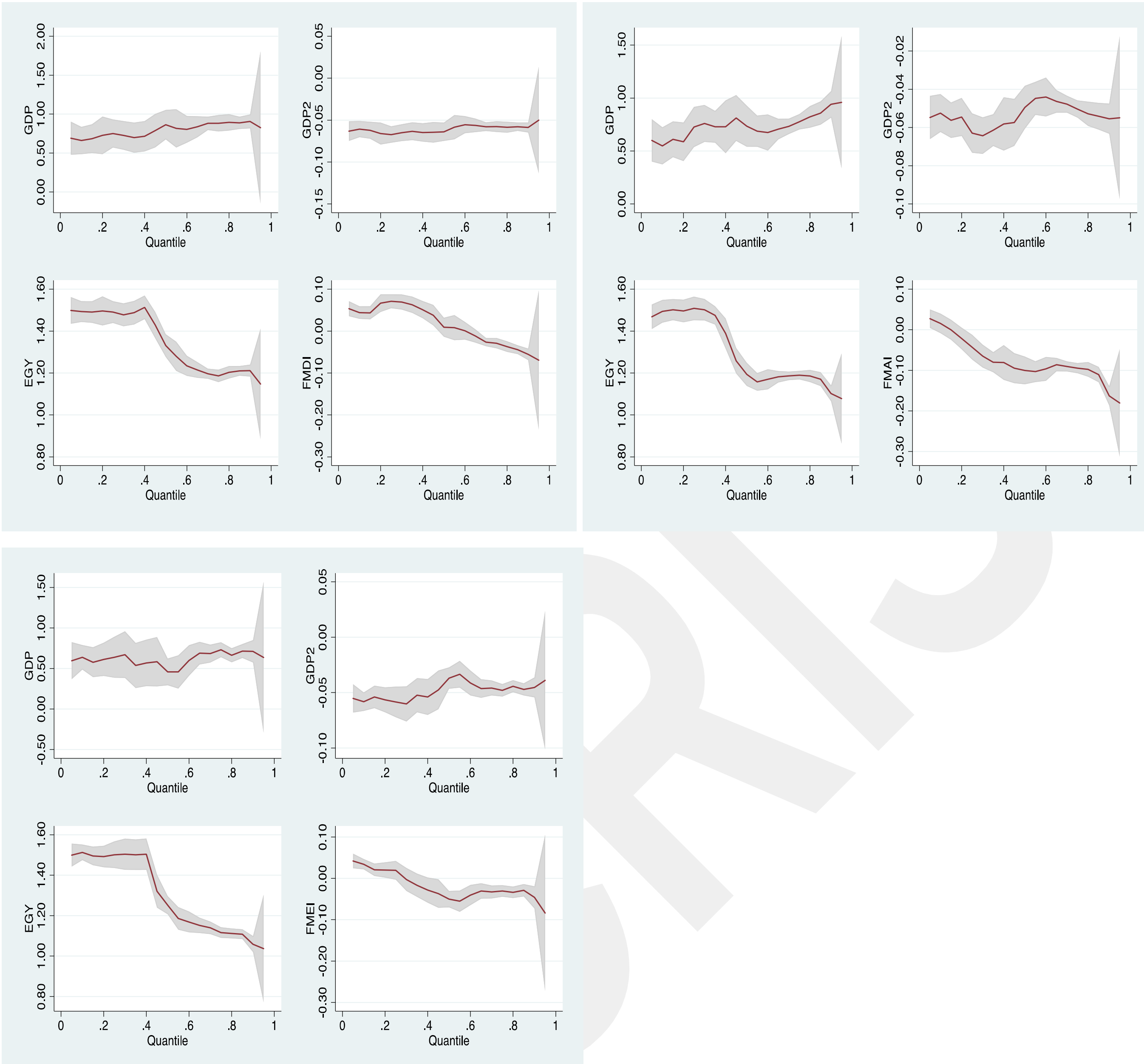

Fig. 1 (*continued*).

economic activities by promoting structural changes and technical changes. These practices are associated with the changes in the industry technology, more focus on the services sector and using less energy-intensive production techniques (Ulucak and Bilgili, 2018).

Moreover, 1% increases in energy consumption (EGY), causing CO_2 emissions to rise. The rise in CO_2 emissions due to EGY is higher for the 25th quantile in all nine models. However, energy consumption effect on CO_2 emissions is positive, but it declines at 50th and 75th quantiles. The coefficients for all nine models are greater than one and this is mainly since CO_2 emissions is derived from the use of fossil fuel consumption. The rise in CO_2 emissions due to EGY for 25th, 50th and 75th quantile coefficients are ranging from 1.50% at maximum to 1.02% minimum value. High energy consumption in these countries is also associated with consumer preferences and the way they live.

These results can further be verified by looking at Fig. 1, which depicts that there is clearly a rise in CO_2 emissions due to EGY at 25th quantile and then there is a sudden decline in the use of energy at 50th and 75th quantiles. The effect of energy is declining, especially at 50th and 75th quantiles; this is mainly due to the rise in renewable energy consumption in the total energy mix of these countries. Referring to the International Renewable Energy Agency (IRENA, 2019), the use of renewable energy consumption has reached 51% in industry and 16% in residential; in detail, 35% in industry and 45% in residential for China; 33% in industry and residential for Iran; 42% in industry and 22% in residential consumption for Japan; 43% renewable energy in industry and 12% for residential purposes for South Korea; 33% renewable energy is used in industry while 21% for residential use for the USA. The rise of renewable energy consumption uses in the energy mix verified that EGY from non-renewable energy sources are declining and holds true for these countries.

The impact of financial development on CO_2 emissions is varying not only for each quantile but also for different proxies of financial development. There are several interesting results that require explanations: First, financial development negatively affects the pollution for high quantile (i.e., 75th quantile) irrespective of the proxy used for financial development. The coefficients of financial development vary from −0.11% to −0.01% except for FIEI which is 0.24% at 75th quantile. Second, in case of FIFI proxy, financial development positively affects emissions for every quantile. This implies that financial institutions access stimulates environmental degradation in sample countries. Third, the coefficient of financial development proxied by financial institutions efficiency index (FIEI) is negative for every quantile, which implies that an improvement in financial institutions efficiency result in lower emissions for every quantile. Fourth, in case of 25% quantile, financial development is positively associated with the pollution for 5 proxies (FMDI, FMEI, FIEI, FMI, FDI) and negatively associated with the pollution for the remaining 4 proxies of financial development (FII, FIDI, FIAI and FMAI). These positive and significant coefficients of financial development (proxied by FMDI, FMEI, FIEI, FMI, FDI) imply that in the initial stages, financial markets increase carbon emissions; however, at a higher quantile then it starts to decline emission level due to improvement. However, we observe the opposite in case of other proxies of financial development such as FII, FIDI, FIAI and FMAI. The negative coefficient for 25th quantiles ranging from −0.15% to −0.01%, while the positive coefficients for 25th quantiles ranging from 0.18% to 0.02%. Fifth, in case of 50% quantile, financial development is positively associated with environmental quality for 5 proxies (FDI, FII, FID, FIEI and FMDI) and negatively associated with emissions for the remaining 4 proxies of financial development (FMI, FIAI, FMAI and FMEI). These positive and significant coefficients of financial development (proxied by FDI, FII, FID, FIEI and FMDI) imply that in the transition phase, financial development stimulates CO_2 emissions; however, in the later phase financial deepening results in low carbon emissions (which is evident from the negative coefficient of financial development at 75% quantile). In case of 75% quantile, financial development is negatively and significantly associated with environmental quality for 7 proxies (FDI, FIEI, FMDI, FMI, FIAI, FMAI and FMEI); however, the relationship is insignificant for the remaining 2 proxies of financial development (FII and FIDI). We infer an interesting conclusion from the results at 50% quantile: Since both financial markets and institutions are in the transition phase and the tipping point has not been attained, hence, financial development is positively associated with emissions. However, once these financial institutions and markets reached to a satiety point then it's to improve the environment. Improved financial system diverts funds to the projects aiming to protect and improve the environmental. Hence, in the later stages of (75% quantile), countries may adopt different environmental protection measures, which result in abating of CO2 emissions. Henceforth, the relationship between financial development and CO2 emissions is not fixed along different quantile. It may change from positive to negative as time passes and we move from short run to long run. Financial development results in extraction of natural resources, which in turn exerts pressure on environment at 50% quantile. However, at 75% quantile, due to increased concentration on environment, financial development results in improving the environmental quality. However, we observe the opposite in case of other proxies of financial development such as FMI, FIAI, FMAI and FMEI. The positive coefficient for 50th quantiles ranging from 0.31% to 0.01% while the negative effect and its coefficients are ranging from −0.31% to −0.01%. These results support the findings of Sachs and Warner (2001), Tang and Tan (2014), Solarin et al. (2017), Shahbaz et al. (2016), Pata (2018), Wang et al. (2019). Moreover, Rajan and Zingales (2003) argue that improved financial system provides opportunities to investors and hence, transfer funds to the productive sectors of the economy.

The results suggest that as compare to other proxies of financial development, financial institutions access index (FIAI) has great influence on CO_2 emissions, which is obvious from high coefficients of these proxies. The main reason for these findings is that since, investors get loans from financial institutions and they are sternly supervised by these institutions. These firms and companies are supposed to strictly follow the social responsibility of environmental protection and employ energy efficient technologies in order to abate carbon emissions. Hence, access to financial institutions has strong impact on emissions. On the other hand, financial markets index (FMI), financial institutions depth index (FIDI) and financial markets access index (FMAI) have small influence on CO_2 emissions, which is obvious from small coefficients of these proxies. The main reason for these findings is that excess financialization of markets and access to these markets provide additional source of equity financing, which results in growing demand of energy consumption and hence contributes more to emissions. These results support the earlier findings of Jiang and Ma (2019a, 2019b).

Fig. 1 verifies the empirical outcomes from Table 5 as the figures for all nine models by using different proxies for financial development are provided. These figures clearly support our results and showing a mixed trend for 25th, 50th and 75th quantiles by using different proxies for financial development. All the results obtained from quantiles regressions analysis are significant at a 1% level. The negative results of financial development are associated with many factors in these countries. Technological innovation especially related to production is important not only for improving production quality but also to control its cost and upgradation of technology requires financial supports from financial institutions and markets. A more developed financial system not only helped to reduce constraints for acquiring financings especially for those projects that helped to ensure an improved infrastructure for energy and reduce carbon emissions. Similarly, these firms acquiring loans are strictly supervised by the financial authorities especially the use of environment friendly technology that eventually help to reduce carbon emissions (Jiang and Ma, 2019a, 2019b). The empirical results support the negative effect of financial development on carbon emissions and verify the above given channel for top-ten emitters.

It is necessary to compare the results obtained with this proposed quantile regression method to what would be obtained using the pre-existing methodologies discussed in the Introduction section. The results obtained from conventional long-run estimators such as ordinary least square with fixed effect (OLS-FE) and fully modified OLS (FMOLS) are given in Table 6. Similar to quantile regression, the results confirmed the EKC hypothesis for the top ten emitters countries. Moreover, the positive effect of energy consumption on carbon emissions is also verified. For financial development, the results are mixed with the negative impact of FD on carbon emissions in case of FDI, FII, FMI, FIAI, FMAI using OLS-FE. In contrast, the effect of FDI on carbon emissions is positive for FMOLS.

In comparison with quantile regression results, FMOLS and OLS-FE results are different in many ways. First, on technical aspects, FMOLS and OLS-FE do not take into account a non-normal data series, slope heterogeneity and outliers; therefore, these results are not reliable. Second, for panel quantile regression, disaggregate effect of each quantile is obtained, i.e., for 25th,50th & 75th. On the policy implications side, the results of FMOLS and OLS-FE may provide misleading results since it does not give a heterogeneous effect of each quantile. For example, the policy implications for financial development may suggest a deteriorating effect on carbon emissions; however, at different quantiles, the effect may possibly be negative. Therefore, policymakers may consider that specific level of a threshold for financial development before designing any policy. Similarly, the impact of energy consumption may not be positive and constant through each quantile, as in our results at a higher quantile, energy consumption is falling and have a negative effect on carbon emissions relative to the first and second quantile. Based on our reasoning, this study is different not only by using nine different indexes of financial development but also employ a robust methodology.

4. Conclusion and policy implications

On the role of financial development and carbon emissions, extensive amount of literature is available; however, none of these studies

Table 5
Results of quantile regression for nine proxies.

	Proxy for FD: FDI			Proxy for FD: FII			Proxy for FD: FMI		
	q0.25	q0.50	q0.75	q0.25	q0.50	q0.75	q0.25	q0.50	q0.75
GDP	0.75**	0.84**	0.77**	0.62**	0.79**	0.84**	0.70**	0.78**	0.75**
GDP^2	−0.06**	−0.06**	−0.05**	−0.05**	−0.05**	−0.05**	−0.06**	−0.05**	−0.05**
EGY	1.50**	1.32**	1.16**	1.50**	1.29**	1.12**	1.50**	1.32**	1.16**
FD	0.07	0.07	−0.11*	−0.01	0.12*	−0.06	0.03	−0.01	−0.05**
CONS	−11.5**	−11.1**	−9.41**	−10.80**	−10.90**	−9.66**	−11.20**	−10.50**	−9.54**
	Proxy for FD: FIDI			Proxy for FD: FIAI			Proxy for FD: FIEI		
	q0.25	q0.50	q0.75	q0.25	q0.50	q0.75	q0.25	q0.50	q0.75
GDP	0.60**	0.87**	0.85**	0.73**	0.84**	0.95**	0.71**	0.59**	0.74**
GDP^2	−0.05**	−0.06**	−0.05**	−0.05**	−0.04**	−0.05**	−0.05**	−0.04**	−0.05**
EGY	1.49**	1.28**	1.13**	1.41**	1.17**	1.02**	1.36**	1.23**	1.26**
FD	−0.01	0.03**	−0.01	−0.15**	−0.17**	−0.17**	0.18*	0.31**	0.24**
CONS	−10.7**	−10.9**	−9.94**	−10.73**	−10.10**	−9.75**	−11.30**	−10.81**	−11.20**
	Proxy for FD: FMDI			Proxy for FD: FMAI			Proxy for FD: FMEI		
	q0.25	q0.50	q0.75	q0.25	q0.50	q0.75	q0.25	q0.50	q0.75
GDP	0.75**	0.86**	0.88**	0.72**	0.73**	0.77**	0.63**	0.45*	0.73**
GDP^2	−0.06**	−0.06**	−0.05**	−0.06**	−0.04**	−0.05**	−0.05**	−0.03**	−0.04**
EGY	1.49**	1.33**	1.18**	1.50**	1.19**	1.18**	1.50**	1.25**	1.11**
FD	0.07**	0.01	−0.02*	−0.04*	−0.10**	−0.09**	0.02	−0.05	−0.03**
CONS	−11.2**	−11.0**	−10.3**	−11.20**	−9.61**	−9.80**	−10.9**	−8.75**	−9.22**

** Denotes the statistical significance at 1% level.
* Denotes the statistical significance at 5% level.

investigated the role of multidimensional index of financial development on carbon emissions. Second, in the modern era, financial sector across the globe is covering wide range of activities and therefore it is imperative to cover the effect of financial development especially using a broad measure that cover not only financial institutions but also financial markets. Similarly, on the methodology side, unlike previous studies, this study uses panel quantile regression analysis which is useful to outliers and provide more reliable estimates for climate policies. Therefore, an attempt is made to analyze the nexus between financialization and carbon emissions for the top-ten emitters of carbon emissions, i.e., Brazil, Canada, China, India, Iran, Japan, the Republic of Korea, Saudi Arabia, the United States of America and South Africa from 1980 to 2014.

For empirical analysis, this study employed the normality test along with cross-section dependence and slope heterogeneity test. Moreover, Im et al. (2003a, 2003b) and cross-sectionally augmented Pesaran (2007) tests are used for checking the stationarity of each data series. The results provide sufficient evidence of heterogeneity and non-normality in the data, which allows us to employ quantiles regression analysis for the association among carbon emissions, financialization, energy consumption, gross domestic product and the square of GDP. Similarly, cointegration is tested employing Westerlund (2007) test. The results verified long-run cointegration relationship among all variables employing different proxies for nine models.

The outcomes from quantile regression analysis verified a statistically significant and positive relationship between gross domestic product (GDP) and carbon emissions. In contrast, the square of GDP has a negative effect on carbon emissions. In the case of selected top-ten emitters for this study, these findings validate the existence of the environmental Kuznets curve (EKC). The effect of GDP on each quantile is different as at 25th quantile; the coefficients are found to have a higher effect for most of the models, while the lower effect is found at 75th quantile.

Similarly, energy consumption (EGY) increases carbon emissions with a strong effect is found through 25th and 50th quantiles. In contrast, financial development, which is measured through nine different

Table 6
Results from conventional long-run estimators.

a) OLS with fixed effect

Coeff.	Proxy: FDI	Proxy: FII	Proxy: FMI	Proxy: FIDI	Proxy: FIAI	Proxy: FIEI	Proxy: FMDI	Proxy: FMAI	Proxy: FMEI
GDP	0.96**	0.97**	0.95**	0.98**	0.99**	0.99**	0.96**	0.95**	0.94**
GDP^2	−0.04**	−0.04**	−0.04**	−0.05**	−0.05**	−0.05**	−0.05**	−0.04**	−0.05**
EGY	0.76**	0.75**	0.76**	0.75**	0.76**	0.74**	0.72**	0.75**	0.77**
FD	−0.02	−0.02	−0.01	0.001	−0.03	0.02	0.02*	−0.001	−0.02
CONST	−8.70**	−8.66**	−8.72**	−8.74**	−8.81**	−8.84**	−8.45**	−8.69**	−8.64**

b) FMOLS

Coeff.	Proxy: FDI	Proxy: FII	Proxy: FMI	Proxy: FIDI	Proxy: FIAI	Proxy: FIEI	Proxy: FMDI	Proxy: FMAI	Proxy: FMEI
GDP	1.08**	1.09**	1.06**	1.07**	1.04**	1.11**	1.06**	1.08**	1.02**
GDP^2	−0.05**	−0.06**	−0.06**	−0.06**	−0.05**	−0.06**	−0.05**	−0.06**	−0.05**
EGY	0.81**	0.81**	0.81**	0.79**	0.81**	0.81**	0.76**	0.81**	0.82**
FD	0.01	0.04	−0.001	0.04	0.001	0.05	0.03*	0.001	−0.02*

** Denotes the statistical significance at 1% level.
* Denotes the statistical significance at 5% level.

proxies by running nine different models. The result shows that the effect of financial development is positive on 25th quantile for most of the models. However, the effect of financial development for all the models are negative at 75th quantile.

Following the empirical outcomes, this study provides the following policy recommendations:

- Since financial institutions lack the environmentally friendly policies, which result in high carbon emissions. Hence, it is suggested to strengthen the institutions and adopt ecofriendly policies to ensure low carbon emissions.
- To attain low carbon emissions and sustainable development, countries need a viable financial institution that focus on green growth strategies by promotion of cleaner production process in order to ensure reduction in carbon emissions.
- Since, the results suggest that in the initial stages, financial markets increase carbon emissions; however, once these financial institutions and markets attained a threshold level then it starts to decline emission level. Hence, it is suggested for countries to improve the financial system so that to achieve the threshold level financial development.
- It is suggested to promote environmental-friendly financing strategies for firms that are complying to the environmental policies of each countries and to promote technological innovation that are in line with cleaner production processes.

A limitation of this study is the use of time period. As larger dataset becomes available this research can be extended and replicated. In addition, this research can be expanded by utilizing panel data for different regions and groups; such as, G-7 and emerging countries. A further research is also required whether the relationship between financial development and CO_2 emissions depends on other factors such as institutional development and market system. The empirical analysis of the study should motivate a similar study for other developed and developing countries of the World.

CRediT authorship contribution statement

Azka Amin: Methodology, Writing - review & editing. **Eyup Dogan:** Supervision, Methodology, Writing - review & editing. **Zeeshan Khan:** Methodology, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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