Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Financial Inclusion and CO2 Emissions in Asia: Implications for Environmental Sustainability

Shahzad Hussain
Foundation University Islamabad
Tanveer Ahmad
Kohat University of Science and Technology
Syed Jawad Hussain Shahzad (j.syed@montpellier-bs.com)
Montpellier Business School

Research Article

Keywords: Financial inclusion, climate change policy, carbon emissions, Asia

Posted Date: February 26th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-245990/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Abstract

We examine the relationship between financial inclusion and carbon emissions. For this purpose, we develop a composite indicator of financial inclusion based on a broad set of attributes through principal component analysis (PCA) for 26 countries in the Asia region. Our robust panel regression analysis reveals a significant positive long-term impact of financial inclusion on carbon emissions. The pairwise causality test reveals unidirectional long-term causality running from financial inclusion to carbon emissions. The study suggests that policy makers may design policies that integrate accessible financial systems into climate change adaptation strategies in order to neutralize the side effect of financial inclusion deteriorating environmental quality and inclusive sustainable economic growth.

JEL Classification

O16; O44, Q54

1. Introduction

The cataclysmic consequences of climate change for human life, health and environmental sustainability have received worldwide attention. Primarily, increased global warming is attributed to anthropogenic greenhouse gas emissions due to massive consumption of fossil fuels and industry discharge (Wawrzyniak and Doryń, 2020). It is widely thought that carbon dioxide is the main cause of environmental degradation among the greenhouse gasses (hereafter GHGs) since it contributes 70% of GHG emissions (Sarkodie et al., 2020). It is widely claimed that the concentration of GHGs in the atmosphere could double from the pre-industrial level by 2035 (Charfeddine and Kahia, 2019). Consequently, worldwide temperature rise may surpass the threshold of 2°C, and if so, the world may experience disastrous consequences of climate change affecting all aspects of life in the form of a rapid rise in sea levels, mass extinction, super droughts, water contamination and health problems (Mujtaba and Shahzad, 2020; Wang et al., 2020; Lu, 2018).

The threat of environmental degradation has directed the attention of scholars to the causal interaction between macroeconomic variables and environmental pollutants. For instance, previous literature ascertains the association between carbon emissions and economic growth (Le et al., 2019), energy consumption (Charfeddine and Kahia, 2019), foreign direct investment (Sarkodie et al., 2020), foreign finance (Alshubiri and Elheddad, 2019), trade openness (Shahbaz et al., 2017), urbanization (Raghutla and Chittedi, 2020), population growth (Yeh and Liao, 2017) and financial development (Jiang and Ma, 2019; Kayani et al., 2020; Raghutla and Chittedi, 2020). Nevertheless, empirical studies regarding the association between carbon emissions and the newly emerging concept of financial inclusion are scant. Financial inclusion is considered to be an integral dimension of financial development since it contributes to the development of the financial sector and equips financial intermediaries with sophisticated tools to achieve inclusive sustainable economic growth (Le et al., 2019; Dahiya and Kumar, 2020).

Theoretically, opposing views exist in the literature regarding the impact of financial inclusion on environmental sustainability (Le et al., 2020). On the one hand, financial inclusion enables the individual as well businesses to avail themselves of useful credit schemes at lower cost which makes the investment in green technology more affordable (Gök, 2020). This way, an inclusive financial system positively contributes to environmental sustainability by encouraging individuals and businesses to use green technology and adopt better environmental practices, which in turn lead to a reduction in GHG emissions (Jiang and Ma, 2019). On the other hand, an accessible financial system may damage environmental quality, thereby boosting manufacturing and industrial activity through affordable financing, which in turn increases CO_2 emissions (Charfeddine and Kahia, 2019). Likewise, financial inclusion also motivates individual consumers to use energy intensive electric appliances (Gök, 2020). The use of these energy intensive goods poses a serious threat to environmental sustainability. So far, two empirical studies, Le et al. (2020) and Renzhi and Baek (2020), establish the relationship between financial inclusion and CO_2 emissions. However, the findings of these studies are contradictory and inconclusive.

We contribute to the literature in two ways. Firstly, we investigate the impact of financial inclusion on climate change in Asian countries. We consider Asia as the sample region for the following reasons. Firstly, recent statistics show Asia to have the most dynamic and fastest growing economies (Le et al., 2019). However, despite achieving significant economic progress, a lack of access to financial services and climate change remain two critical challenges to the region's achievement of inclusive economic development (Le et al., 2019; Le et al., 2020). Home to two-thirds of the world's poor, almost a billion people have neither a formal bank account nor access to any financial services (Bhardwaj et al., 2018). Bhardwaj et al. (2018) report that within the developing economies across Asia, about 27% of adults hold a formal bank account and about 33% have utilized either a loan or credit facility. Much effort has been put into including the masses in the financial sector; however, it is still very challenging to achieve financial inclusion at a maximum level mainly due to contextual differences across countries, which vary along political, economic, cultural, ethnic and religious lines. Secondly, Asia has been the biggest contributor to global warming over the last decade, contributing one-third of total GHG emissions (see the level of CO_2 emissions in Figure 1). Therefore, Asia is very vulnerable to the devastating impacts of climate change (Le et al., 2020).

The second way in which our study contributes to the literature, is that it differs from recent notable studies, such as Le et al. (2020) and Renzhi and Baek (2020), which ignore the issues of long-short causality, pairwise causality, endogeneity, heteroscedasticity and simultaneity problems, in three ways. Firstly, we apply the method of Dumitrescu and Hurlin (hereafter D-H) (2012) to test the pairwise causality and determine the direction of the causal relationship. Secondly, we apply the panel autoregressive distributed lag (ARDL) model to examine the long and short run impact of financial inclusion on carbon emissions. Thirdly, we test this relationship in a dynamic panel framework through the method of Arellano and Bond (1991) using the difference generalized method of moments (GMM) and system GMM, in order to produce consistent and efficient parameters and thereby overcome the endogeneity, heteroscedasticity and simultaneity problems (Muhammad, 2019), as a robustness check. The results are further validated through seemingly unrelated regression (hereafter SUR) for a second robustness check.

2. Literature Review

Financial inclusion is an inextricable part of financial development (Le et al., 2020). Therefore, the theoretical and empirical foundations of financial development are covered in order to establish the link between financial inclusion and carbon emissions.

Theoretically, there exist divergent views among researchers regarding the relationship between financial development and climate change (Jiang and Ma, 2019). On one hand, scholars suggest that financial development mitigates GHG emissions by facilitating the energy supply sector to upgrade production technology and equipment through the mitigation of financial constraints by lower borrowing cost (Renzhi and Baek, 2020). Hence, it is evident that the development of the financial sector, which shows the real availability of capital and funding channels through banks and stock markets, can positively contribute to environmental sustainability via the reduction of GHG emissions (Gök, 2020). From this perspective, financial development reduces environmental deterioration (Koshta et al., 2020). Several empirical studies acknowledge the positive role of financial development in combating climate change (Charfeddine and Kahia, 2019; Omri et al., 2015; Shahbaz et al., 2013; Tamazian and Rao, 2010). Saidi and Mbarek (2017) investigate the impact of financial development on CO2 emissions in a dynamic panel framework setting using time series data on 19 emerging economies over the period 1990-2013. The empirical results show a negative influence of the development of financial systems on CO2 emissions, which shows that financial development positively contributes to environmental sustainability. Using data on the top 23 renewable energy-using countries from 1985 to 2011, Dogan and Seker (2016) analyse the impact of financial development on CO2 emissions based on dynamic ordinary least squares (DOLS) and fully modified ordinary least square (FMOLS). The study reveals that financial development and CO2 emissions are cointegrated in the long run and financial development reduces GHG emissions.

However, other scholars suggest that financial development exacerbates environmental deterioration via an upsurge in CO2 emissions for the following reasons. Firstly, a well-functioning financial system lowers the cost of borrowing, which encourages businesses to obtain the capital required to expand production, which in turn increases CO2 emissions (Raghutla and Chittedi, 2020). Secondly, financial development dramatically promotes social consumption thereby providing better credit utilization, which could facilitate individual consumers purchasing more energy intensive goods such as electrical appliances (Gök, 2020), automobiles and many others, which in turn increases CO2 emissions (Koshta et al., 2020). Thirdly, capital markets are considered important indicators of economic development. The persistent performance of the stock market attracts individual and institutional investors and stimulates the activities of production and consumption, which in turn increase CO2 emissions through massive consumption of fossil fuels (Rajpurohit and Sharma, 2020). From this perspective, environmental deterioration increases with financial development. This claim is supported by several empirical studies such as Al-Mulali et al. (2015), Kayani et al. (2020), Jiang and Ma (2019) and Pata (2018). Based on data from 12 Asian countries over the period 1993–2013 and a panel causality test, Lu (2018) reveals that financial development contributes to environmental degradation. Considering financial inclusion to be an inextricable part of financial development, Le et al. (2020) investigate the causal relationship between financial inclusion and CO2 emissions based on Driscoll-Kraay standard errors and annual panel data from 31 Asian countries from 2004 to 2014. The empirical findings reveal that financial inclusion contributes to environmental deterioration, thereby increasing CO2 emissions. Cetin, Ecevit and Yucel (2018) examine the long- and short-run causal impact of financial development on CO2 emissions in Turkey from 1960 to 2013 in a panel setting framework. The findings reveals a positive impact of the development of financial systems on CO2 emissions and a unidirectional relationship running from financial development to CO2 emissions. Using the ARDL approach, Ali et al. (2019) examine the causal relationship between financial development and CO2 emissions in Nigeria from 1971 to 2010. They find positive long- and short-run relationships between financial development and CO2 emissions. The findings reveal that that the development of financial systems leads to further environmental degradation.

The third school of thought supports the nonlinearity of the relationship between financial development and CO2 emissions. Several studies find an inverted U-shaped relationship between financial development and GHG emissions (Omri et al., 2015; Salahuddin et al., 2018; Shahbaz et al., 2013). Hung et al. (2018) examine the impact of the development of financial systems on CO2 emissions in 25 OECD countries from 1971 to 2007. The empirical results show nonlinearity between financial development and CO2 emissions. Renzhi and Baek (2020) examine the impact of financial inclusion on CO2 emissions in an environmental Kuznets curve (EKC) framework based on 103 countries, and support the inverted U-shaped relationship. Zaidi et al. (2019) analyse the link between financial development and CO2 emissions based on advanced statistical tests such as updated bias-corrected and continuously updated fully modified estimators in 17 APEC countries from 1990 to 2016 using an EKC framework. The findings show development of financial systems to be negatively associated with CO2 emission in the long and short run.

We can infer from the above literature review that both theoretically and empirically the impact of financial system development on CO2 emissions is still under debate and the results remain inconclusive. More specifically, the literature provides only two recent studies of the relationship between the recently emerged concept of financial inclusion and climate change. These studies offer useful insights and advance the literary work, but the findings regarding the financial inclusion-carbon emission nexus are contradictory and inconclusive. Primarily two gaps exist in the literature regarding this topic. Firstly, most previous studies focus on developed and emerging economies, while the region most vulnerable to climate change (Asia) has had the attention of only one empirical study so far. Secondly, the application of different statistical techniques, samples and data create challenges for comparing the research completed by the various scholars. Keeping the above limitations in view, our work relates to the small number of studies that examine the financial inclusion-carbon emission nexus through advanced statistical techniques such panel ARDL, difference GMM, system GMM and SUR to provide insight for policy makers on this topic.

3. Data And Research Methodology

3.1. Operationalization - Financial Inclusion and Carbon Emission

We categorize the variables into an independent variable (financial inclusion), a dependent variable (carbon emission) and control variables (trade openness, energy consumption, industry) for empirical analysis. These are described in Table 2. We collect the data for proxies of financial inclusion from the Global Findex database. The data for the remaining macro variables are extracted from the World Development Indicators (WDI) for the 26 sample countries: Brunei

Darussalam, Iraq, Israel, Japan, Kazakhstan, Republic of Korea, Kuwait, Lebanon, Malaysia, Qatar, Saudi Arabia, Singapore, United Arab Emirates, Bangladesh, Bhutan, Cambodia, India, Indonesia, Jordan, Kyrgyz Republic, Mongolia, Pakistan, Philippines, Sri Lanka, Tajikistan and Vietnam.

Table 2 presents the summary statistics of the variables for the 26 selected Asian countries. The means and standard deviations of carbon emission (M = 8.546, SD = 11.108) and energy consumption (M = 3122.33, SD = 4095.72) are comparatively greater than the reported values of Nathaniel and Adeleye (2021) for the African region. The results are in line with idea that Asia as a region is very vulnerable to climate change. The summary of the financial inclusion proxies reveals that mean values of branches of commercial banks per 100,000 adults and ATMs per 100,000 adults are close to the mean values of these proxies given in Le et al. (2020), while outstanding deposits (% GDP) and loans (%GDP) are consistent with the study of Le et al. (2019). Among the control variables, the average and standard deviation of energy consumption are greater than those of trade openness (M = 4.489, SD = 0.546) and industry (M = 3.547, SD = 0.420). All the variables are normalized by taking the natural log of each variable for further analysis.

Our variable of interest is the financial inclusion index. We construct a composite indicator of financial inclusion based on four widely used proxies: branches of commercial banks per 100,000 adults, number of ATMs per 100,000 adults, the amount of bank deposits and the amount of bank credit (Chatterjee, 2020; Le et al., 2020). These proxies cover two keys aspects of an inclusive financial system; the two former indicators demonstrate the availability of the banking sector and the two latter indicators demonstrate the use of banking system (Van et al., 2019).

We use the principal component analysis (PCA) technique to estimate the financial inclusion index. The PCA is the most widely used technique for creating indexes in the literature for several reasons. Firstly, it is a widely known standard technique that extracts hidden features and relationships and removes excess information in order to reduce the dimensionality of data and create a composite indicator (Radovanović, Filipović and Golušin, 2018). Unlike other linear transformation techniques with fixed sets of basis vectors, the PCA basis vectors depend on the dataset. We apply two tests, Bartlett's test and the Kaiser-Meyer-Olkin (KMO) test, prior to the PCA estimation in order to determine whether the stated proxies are appropriate for the construction of financial inclusion. Bartlett's test of sphericity tests whether the correlation matrix is an identity matrix (Le et al., 2019). Factor analysis is considered to be more suitable in the case of a significant Bartlett's test ($P < 0.05$). The KMO test reveals the proportion of common variance that might be caused by underlying factors (Renzhi and Baek, 2020). The KMO index ranges from 0 to 1, with scores larger than 0.5 generally indicating that the factor analysis is suitable. The results of these two tests are reported in Tables 3 and 4. The results of both tests support the use of PCA in this study.

We use PCA to construct the financial inclusion index. The PCA process is executed in two steps. First, we estimate the various components in order to identify which components account for the variations in the original variable and have the lowest pairwise correlation. In the second step, following Gujarati and Porter (2009), we estimate the index based on the components which account for a portion of variance with eigenvalues greater > 1. The cumulative variations of each component are presented in Table 4.

3.2. Econometric Approach

We use the theoretical foundation of stochastic impacts by regression on population, affluence and technology (STIRPAT) (Dietz and Rosa, 1997), to examine the impact of financial inclusion on CO2 emissions in Asia. The proposed STIRPAT model is:

$$I_{it} = \delta_0 + \delta_1 P_{i,t} + \delta_2 A_{i,t} + \delta_3 T_{i,t} + \varepsilon_{i,t} \qquad (1)$$

where I_{it} stands for environmental effects and the factors included are P_{it} (population), A_{it} (affluence) and T_{it} (technology) for country i at time t. We extend the above STIRPAT model to incorporate financial inclusion. In light of the existing literature, we also include three relevant control variables, trade openness (Shahbaz et al., 2017), energy consumption (Charfeddine and Kahia, 2019) and industrialization (Zhou et al., 2013). The baseline model is:

$$Co2_{i,t} = \delta_0 + \delta_{i,t} FI_{i,t} + \sum_{t=1}^{t=n} \delta_{i,t}\, Controls_{i,t} + \varepsilon_{i,t} \qquad (2)$$

where $Co2_{i,t}$ stands for the log of CO2 emissions and $FI_{i,t}$ represents the financial inclusion index. The control variables are trade openness, energy consumption and industry.

We execute the data analysis in six steps. First, we check the cross-sectional dependency through Pesaran (2004) and Pesaran (2015) tests and then perform the D-H test to examine the pairwise causality of the variables. In the second step, we test the stationarity of the data through widely used unit roots tests (CIPS, IPS, Fisher-ADF, Fisher-PP, Hadri, LLC) (Hasanov et al., 2017; Jiang and Ma, 2019). In the third step, the cointegration among the analysed variables is tested through the methods of Pedroni (2004), Kao (1999) and Westerlund (2005). In the fourth step, we apply the panel ARDL to establish the long- and short-run exogenous and endogenous relationships. The pooled mean group (hereafter PMG) estimator and mean group (hereafter MG) estimator are two widely used estimators of ARDL. We apply the panel ARDL for the following reasons: (i) the long- and short-run cointegrating vectors are considered heterogeneous across panels in the MG approach, while the PMG assumes the estimating parameters of the cointegrating vector are homogenous across panels which increases the degree of freedom (df); and (ii) the PMG produces efficient and consistent estimations even in the presence of a small number of observation across sections (Da et al., 2018; Mensah et al., 2019; Žiković et al., 2020). Based on the Hausman test results, the PMG is more suitable for data analysis. Hence, the following equation is estimated to empirically test the relationship between financial inclusion and CO2 emissions:

$$\Delta y_{i,t} = \Phi_i y_{it-1} + \beta_i x_{it} + \sum_{j=1}^{pi-1} \Psi_{ij}\, \Delta y_{it-j}{}_{\,i,t} + \sum_{j=0}^{qi-1} \delta_{ij}\, \Delta x_{it-j} + \alpha_i + \varepsilon_{it} \qquad (3)$$

where y_{it} is the dependent variable, x_{it} is a vector of the explanatory variables financial inclusion index, trade openness, energy consumption and industry, all integrated of order 1, *Φ_i is the error correction coefficient, βi is the long-run parameter, Ψ_{ij} and δ_{ij} are county-specific coefficients of the short-term dynamics, pi and qi are lag lengths of the autoregressive distributed lag model, α_i represents county-specific intercepts and ε_{it} is an IID error term.*

We test the causal impact of financial inclusion on CO2 emissions in a dynamic panel framework setting using the SUR method. Following Bashir and Khan (2019), we apply the methods of Arellano and Bond (hereafter AB) (1991) and Blundell and Bond (hereafter BB) (1998) for robustness checks. Dynamic panel models are considered more effective at handling problems of unobserved heterogeneity and simultaneous and dynamic endogeneities in the panel data, and are found to provide consistent and unbiased coefficients. Furthermore, following Bashir (2019), we apply SUR in order to validate the findings.

4. Empirical Results

4.1. Cross-Sectional Dependence and the Dumitrescu and Hurlin Causality Test

We used the Pesaran (2004) and Pesaran (2015) tests for cross-sectional dependence (CD). These tests are suitable for larger cross-sections and smaller time series data such as those of the current research (N = 26 > T = 12). Table 5 presents the results of both tests. Under the null hypothesis, there is cross sectional independence. The results of the CD tests reject the null hypothesis of cross-sectional independence and accept the alternate hypothesis of cross-sectional dependence, since all the stated variables are statistically significant at 1.00%. These results are in line with the findings of Le et al. (2020). Hence, the results support the presence of cross-sectional dependence among the variable across all the Asian countries.

We examine the pairwise causality between financial inclusion and carbon emissions in a panel data framework setting through the D-H test, and the results are presented in Table 6. The statistical technique is based on individual Wald statistics values of Granger non-causality averaged across cross-section units. The null hypothesis supports the absence of causality for individual variables in the panel data. Keeping in view the short time dimension of our data, we use lag order one, following the methodology of Žiković et al. (2020). The results of the D-H test reveal a unidirectional relationship running from financial inclusion to CO2 emissions, since financial inclusion Granger causes carbon emissions, but the opposite does not hold. The results are consistent with the findings of Ali et al. (2019).

4.2. Panel Unit Root Tests and Cointegration

We test the stationary of the data through commonly used panel unit root tests (hereafter PURT) CIPS, IPS, Fisher-ADF, Fisher-PP, Hadri, LLC (Hasanov et al, 2017; Jiang and Ma, 2019) to determine whether the variables are integrated at the level I(0) or first difference I(1) and avoid the problem of spurious regression (Granger and Newbold, 2014). Table **7** presents the results of the PURTs. It can be seen that all the variables are integrated at I(1) with few exceptions, implying that all the variables are stationary at order one.

The method of Pedroni (2004) is applied to test the cointegration among the variables. This test is suitable in cases of large N and small T (N>T or 26). Table 8 present the results. Of the seven tests of cointegration, four support the existence of long-run cointegration among the variables. The methods of Kao (1999) and Westerlund (2005) are also used as a robustness check. Both tests support the existence of long-run relationships among the variables. The findings of the robustness tests provide stronger proof of cointegration amongst the analysed variables. Hence, we draw a conclusion based on the results that there is a long-run relationship among the variables in the Asia region.

4.3. Regression Results

We test the long- and short-run relationships between financial inclusion and carbon emissions in a panel ARDL framework setting. We decide between the PMG and MG estimators using Hausman's test of slope homogeneity (Mensah et al., 2019; Žiković et al., 2020). The results presented in Table 9 reveal that that the PMG estimator is more suitable for the analysis. We apply the PMG estimator using an ARDL(1,1,1,1,1) based on the Schwarz information criteria (SIC).

The PMG estimator reveals that financial inclusion significantly and positively influences carbon emissions in the long run. The short-term coefficient is also statistically significant, which implies that financial inclusion positively affects CO2 emissions. The positive signs of the long- and short-run coefficients show that the activities related to financial inclusion and environmental deterioration are closely associated with each other. Our findings support the theoretical idea that an accessible financial system offers a well-developed mechanism of risk mitigation, efficient resource pooling and strong corporate governance, as well as boosting industrial activities for better economic prospects which lead to further environmental degradation. However, our results contrast with the theoretical proposition that the development of financial systems positively contributes to environmental sustainability via a reduction in GHG emissions, facilitating individuals and businesses making investments in upgraded green technology by mitigating financial constraints and lowering borrowing costs. Our findings are similar to Jiang and Ma (2019) and Le et al. (2020), whose empirical results also support the claim that accessible financial systems exacerbate environmental quality.

4.4. Robustness Checks

Our previous findings based on the PMG estimator confirm the positive influence of financial inclusion on carbon emissions. However, we apply two further robustness checks to verify the reliability of the empirical results. We examine the financial inclusion-carbon emissions relationship in a panel data framework. Hsiao (1986) argues that panel regression estimation has several benefits. Firstly, the panel estimation allows us to account for unobserved heterogeneity. Secondly, large numbers of observations provide more degrees of freedom. Thirdly, it allows us to control for unobservable county-specific characteristics which may be correlated with our exogenous variables (Renzhi and Baek, 2020). Hence, following Bashir and Khan (2019) and Bashir (2019), we test the relationship using dynamic panel regression estimations and SUR in order to obtain consistent and efficient regression coefficients. Table 10 presents the

estimation results of the dynamic panel models. The findings of the post-estimation tests support the appropriateness of the GMM specification. The coefficients of financial inclusion in the AB and BB models are positive and statistically significant at the 1% level, which implies that financial inclusion may further exacerbate environmental degradation. The results are consistent with our findings. Similarly, Table 11 shows the results of the SUR model, which further validate our previous findings.

The overall results support the claim that a developed financial system accumulates capital through pooling and mobilization of savings, reduces the problem of asymmetric information regarding investment opportunities and ensures the optimal allocation of available financial resources (Kayani et al., 2020), which in turn lubricates the wheels of the economy and accelerates economic growth (Le et al., 2019), consequently increasing CO2 emissions (Raghutla and Chittedi, 2020). This is consistent with the theoretical stance that financial development leads to economic prosperity which further deteriorates environmental sustainability. Our findings share common ground with several empirical studies such Al-Mulali, Ozturk and Lean (2015) and Kayani et al. (2020). These studies support the idea that financial development leads and environmental degradation follows.

5. Conclusion

Massive unmoderated development has created several challenges including environmental deterioration and climate change. Global warming is a serious threat to the existence of human beings and has thus been considered a primary concern over the last couple of decades. The literature provides theoretical and empirical support regarding the major macroeconomic determinants of climate change such as economic growth, energy consumption, population and financial development. Recently, financial inclusion has attracted worldwide attention in the fight to combat climate change. Therefore, we examine the impact of financial inclusion on carbon emissions in 26 Asian countries through series of advanced statistical techniques in order to provide insight for policy makers. Our findings reveal a positive relationship between financial inclusion and CO2 emissions. The results are consistent with idea that financial inclusion, which facilitates individuals and businesses obtaining easy access to financial services, motivates businesses to expand the scale of production and increases the power of individual consumers to purchase energy intensive electric appliances which accelerate the use of energy from fossil fuels, resulting in higher CO2 emissions. Our findings are qualitatively robust across econometric models such as PMG, ARDL, AB, BB and SUR.

Our findings have far reaching implications for Asian countries, providing insights for policy makers regarding the linear positive relationship between financial inclusion and carbon emissions. Policy makers need to interpret the results of this research with great caution. They may incorporate accessible financial systems into climate change adaptation strategies in such a way as to considerably reduce carbon emissions. For instance, under the widely acknowledged green credit guidelines of China, the financial system provides adequate support through green credit financial services to reduce carbon emissions and contribute to the green economy and sustainable development. Secondly, regulatory authorities may align initiatives for financial inclusion with environmental protection policies. Governments may uplift marginalized segments of society by expanding inclusive finance in a way that addresses environmental deterioration. Moreover, small and medium enterprises (SMEs) could be encouraged to adopt carbon mitigation practices through easy access to green financial services. Investments based on public-private partnerships that work towards environmental sustainability are part of the sustainable development goals (SDGs). Thirdly, businesses tend to expand their production through financial loans instead of investment in green technology projects, since developing countries are under extreme pressure to develop economically, which leads to further climate change. This shows the unavoidable contradiction of economic development and environmental sustainability. However, we suggest that sustainable inclusive growth can be achieved with the help of policies that lead to synergies between growing financial inclusion and mitigating CO2 emissions.

Our study covers the Asia region and subsamples to establish the relationship between financial inclusion and carbon emissions. However, future studies could consider individual countries, which have various political, economic, cultural, ethnic and religious attributes. Secondly, future research could consider a larger number of countries across developed, emerging and developing markets in order to provide insights for policy makers, foreign investors, fund managers and other stakeholders. Thirdly, future studies could explore the role of levels of governance on the relationship between financial inclusion and various proxies of climate change. Fourthly, another interesting area for research would be the construction of financial inclusion based on a broader set of fundamental attributes such as penetration, availability and usage of financial systems in each country or region in order to broaden the understanding of policy makers related to the non-linear relationship between financial inclusion and climate change.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The date used in this study is available on the official website of the OECD and Bloomberg.

Competing interests

The authors declare that they have no competing interests

Funding

Not applicable

Authors' contributions

SJ and TA conceptualized the idea, did the analysis and wrote the initial draft. SJHS reviewed and proof-read, and also supervised the work.

Acknowledgements

Not applicable

References

Ali, H. S., Law, S. H., Lin, W. L., Yusop, Z., Chin, L., & Bare, U. A. A. (2019). Financial development and carbon dioxide emissions in Nigeria: evidence from the ARDL bounds approach. *GeoJournal, 84*(3), 641-655.

Al-Mulali, U., Ozturk, I., & Lean, H. H. (2015). The influence of economic growth, urbanization, trade openness, financial development, and renewable energy on pollution in Europe. *Natural Hazards, 79*(1), 621-644.

Alshubiri, F., & Elheddad, M. (2019). Foreign finance, economic growth and CO2 emissions Nexus in OECD countries. *International Journal of Climate Change Strategies Management,12*(2), 161-181.

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The review of economic studies,58*(2), 277-297.

Bashir, M. (2019). Energy consumption, CO2 emissions and economic growth in developed, emerging and Middle East and North Africa countries. *Energy,179*(1), 232-245.

Bashir, M., & Khan, S. (2019). Effect of bilateral FDI, energy consumption, CO2 emission and capital on economic growth of Asia countries. *Energy Reports,5*(1), 1305-1315.

Bhardwaj, M., Hedrick-Wong, Y., & Howard, T. (2018). Financial inclusion for Asia ' s unbanked. The World Bank Blogs.Phublished on April 30,2020.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics, 87*(1), 115-143.

Cetin, M., Ecevit, E., & Yucel, A. G. (2018). The impact of economic growth, energy consumption, trade openness, and financial development on carbon emissions: empirical evidence from Turkey. *Environmental Science Pollution Research,25*(36), 36589-36603.

Charfeddine, L., & Kahia, M. (2019). Impact of renewable energy consumption and financial development on CO2 emissions and economic growth in the MENA region: A panel vector autoregressive (PVAR) analysis. *Renewable Energy, 139*(1), 198-213.

Chatterjee, A. (2020). Financial inclusion, information and communication technology diffusion, and economic growth: a panel data analysis. *Information Technology for Development, 26*(3), 607-635.

Da Silva, P. P., Cerqueira, P. A., & Ogbe, W. (2018). Determinants of renewable energy growth in Sub-Saharan Africa: Evidence from panel ARDL. *Energy, 156*(1-22), 45-54.

Dahiya, S., & Kumar, M. (2020). Linkage between Financial Inclusion and Economic Growth: An Empirical Study of Emerging Indian Economy. *Vision: The Journal of Business Perspective, 24*(02), 1-10.

Dietz, T., & Rosa, E. A. (1997). Environmental impacts of population and consumption: Research directions. 92-99.

Dogan, E., & Seker, F. (2016). The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. *Renewable Sustainable Energy Reviews,60*(1), 1074-1085.

Dumitrescu, E.-I., & Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling, 29*(4), 1450-1460.

Gök, A. (2020). The role of financial development on carbon emissions: a meta regression analysis. *Environmental Science Pollution Research,27*(1), 1-19.

Gokmenoglu, K. K., & Sadeghieh, M. (2019). Financial development, CO2 emissions, fossil fuel consumption and economic growth: The case of Turkey. *Strategic Planning for Energy the Environment,38*(4), 7-28.

Granger, C. W. J., & Newbold, P. (2014). *Forecasting economic time series*: Academic Press.

Gujarati, D. N., & Porter, D. (2009). Basic Econometrics In: Mc Graw-Hill International Edition.

Hasanov, F., Bulut, C., & Suleymanov, E. (2017). Review of energy-growth nexus: A panel analysis for ten Eurasian oil exporting countries. *Renewable Sustainable Energy Reviews,73*(1), 369-386.

Hsiao, C., 1986. Analysis of Panel Data. Cambridge University Press, Cambridge

Hung, S.-W., Li, C.-M., & Shen, M.-Y. (2018). Regional analysis of the relationship between CO2 emissions and financial development. *International Journal of Global Energy Issues,41*(3),

Jiang, C., & Ma, X. (2019). The impact of financial development on carbon emissions: A Global Perspective. *Sustainability,11*(19), 5241.

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of econometrics,90*(1), 1-44.

Kayani, G. M., Ashfaq, S., & Siddique, A. (2020). Assessment of financial development on environmental effect: Implications for sustainable development. *Journal of Cleaner Production, 261*(1), 1-8.

Koshta, N., Bashir, H. A., & Samad, T. A. (2020). Foreign trade, financial development, agriculture, energy consumption and CO2 emission: testing EKC among emerging economies. *Indian Growth Development Review,20*(1), 1-31.

Le, T.-H., Chang, Y., & Park, D. (2019). Economic development and environmental sustainability: evidence from Asia. *Empirical Economics, 57*(4), 1129-1156.

Le, T.-H., Chuc, A. T., & Taghizadeh-Hesary, F. (2019). Financial inclusion and its impact on financial efficiency and sustainability: Empirical evidence from Asia. *Borsa Istanbul Review,19*(4), 310-322.

Le, T.-H., Le, H.-C., & Taghizadeh-Hesary, F. (2020). Does financial inclusion impact CO2 emissions? Evidence from Asia. *Finance Research Letters,34*(03), 1-18.

Lu, W.-C. (2018). The impacts of information and communication technology, energy consumption, financial development, and economic growth on carbon dioxide emissions in 12 Asian countries. *Mitigation Adaptation Strategies for Global Change,23*(8), 1351-1365.

Mensah, I. A., Sun, M., Gao, C., Omari-Sasu, A. Y., Zhu, D., Ampimah, B. C., & Quarcoo, A. (2019). Analysis on the nexus of economic growth, fossil fuel energy consumption, CO2 emissions and oil price in Africa based on a PMG panel ARDL approach. *Journal of Cleaner Production, 228*(1), 161-174.

Muhammad, B. (2019). Energy consumption, CO2 emissions and economic growth in developed, emerging and Middle East and North Africa countries. *Energy, 179*(1), 232-245.

Mujtaba, G., & Shahzad, S. J. H. (2020). Air pollutants, economic growth and public health: implications for sustainable development in OECD countries. *Environmental Science Pollution Research,27*(30), 1-13.

Nathaniel, S. P., & Adeleye, N. (2021). Environmental preservation amidst carbon emissions, energy consumption, and urbanization in selected african countries: Implication for sustainability. *Journal of Cleaner Production, 285*(1), 125409.

Omri, A., Daly, S., Rault, C., & Chaibi, A. (2015). Financial development, environmental quality, trade and economic growth: What causes what in MENA countries. *Energy Economics, 48*(01), 242-252.

Pata, U. K. (2018). Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: testing EKC hypothesis with structural breaks. *Journal of Cleaner Production,187*(4), 770-779.

Pedroni, P. (2004). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric theory, 20*(3), 597-625.

Pesaran, H. (2004). General diagnostic tests for cross-sectional dependence in panels. *University of Cambridge, Cambridge Working Papers in Economics, 435*.

Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. *Econometric reviews,34*(6-10), 1089-1117.

Raghutla, C., & Chittedi, K. R. (2020). Financial development, energy consumption, technology, urbanization, economic output and carbon emissions nexus in BRICS countries: an empirical analysis. *Management of Environmental Quality: An International Journal ,31*(6), 1-18.

Rajpurohit, S. S., & Sharma, R. (2020). Impact of economic and financial development on carbon emissions: evidence from emerging Asian economies. *Management of Environmental Quality: An International Journal, 31*(3), 1-15.

Renzhi, N., & Baek, Y. J. J. F. R. L. (2020). Can financial inclusion be an effective mitigation measure? evidence from panel data analysis of the environmental Kuznets curve. *Finance Research Letters, 37*(1), 1-8.

Saidi, K., & Mbarek, M. B. (2017). The impact of income, trade, urbanization, and financial development on CO 2 emissions in 19 emerging economies. *Environmental Science Pollution Research,24*(14), 12748–12757.

Salahuddin, M., Alam, K., Ozturk, I., & Sohag, K. (2018). The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO2 emissions in Kuwait. *Renewable Sustainable Energy Reviews,81*(01), 2002-2010.

Sarkodie, S. A., Adams, S., & Leirvik, T. (2020). Foreign direct investment and renewable energy in climate change mitigation: Does governance matter? *Journal of Cleaner Production,263*(1), 1-11.

Shahbaz, M., Kumar Tiwari, A., & Nasir, M. (2013). The effects of financial development, economic growth, coal consumption and trade openness on CO2 emissions in South Africa. *Energy Policy, 61*(02), 1452-1459.

Shahbaz, M., Nasreen, S., Ahmed, K., & Hammoudeh, S. (2017). Trade openness–carbon emissions nexus: The importance of turning points of trade openness for country panels. *Energy Economics, 61*(2), 221-232.

Tamazian, A., & Bhaskara Rao, B. (2010). Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. *Energy Economics, 32*(1), 137-145.

Van, L. T.-H., Vo, A. T., Nguyen, N. T., & Vo, D. H. (2019). Financial Inclusion and Economic Growth: An International Evidence. *Emerging Markets Finance Trade,55*(14), 1-25.

Wang, L., Vo, X. V., Shahbaz, M., & Ak, A. (2020). Globalization and carbon emissions: Is there any role of agriculture value-added, financial development, and natural resource rent in the aftermath of COP21? *Journal of Environmental Management,268*(1), 1-8.

Wawrzyniak, D., & Doryń, W. (2020). Does the quality of institutions modify the economic growth-carbon dioxide emissions nexus? Evidence from a group of emerging and developing countries. *Economic Research-Ekonomska Istraživanja,33*(1), 124-144.

Westerlund, J. (2005). A panel CUSUM test of the null of cointegration. *Oxford Bulletin of Economics Statistics,67*(2), 231-262.

Yeh, J.-C., & Liao, C.-H. (2017). Impact of population and economic growth on carbon emissions in Taiwan using an analytic tool STIRPAT. *Sustainable Environment Research, 27*(1), 41-48.

Zaidi, S. A. H., Zafar, M. W., Shahbaz, M., & Hou, F. (2019). Dynamic linkages between globalization, financial development and carbon emissions: Evidence from Asia Pacific Economic Cooperation countries. *Journal of Cleaner Production,228*(2), 533-543.

Zhou, X., Zhang, J., & Li, J. (2013). Industrial structural transformation and carbon dioxide emissions in China. *Energy policy,57*(1), 43-51.

Žiković, S., Tomas Žiković, I., & Vlahinić Lenz, N. (2020). A disaggregated approach to energy-growth nexus: Micro-regional view. *Energy Strategy Reviews, 28*(1),2-9.

Tables

Table 1. Summary the empirical studies.

Source	Country/Region	Data	Objective	Key findings
Panel A. The Negative relationship of Financial Inclusion/Financial Development with Co2 Emissions				
Saidi and Mbarek (2017)	19 emerging economies	1990-2013	The study investigate the financial development-CO2 emissions nexus.	FD↑ CO 2 ↓
Dogan and Seker (2016)	top 23 renewable energy countries	1985-2011	They analyze the dynamic relationship of development related to financial system and CO2 emissions based on DOLS and FMOLS	FD↑ CO 2 ↓
Omri et al. (2015)	12 MENA economies	1990-2011	They examine the financial development and CO2 emissions through simultaneous-equation panel data model	FD↑ CO 2 ↓
Gokmenoglu and Sadeghieh (2019)	Turkey	1960-2011	They examined long term relationship among development of financial system, energy consumption and CO2 emissions.	FD↑ CO 2 ↓ FUEL CON ↑ CO 2 ↑
Wang, Vo, Shahbaz, and Ak (2020)	China	1995 e 2014	This study investigate the determinants of carbon emissions in STIRPAT framework.	FD ↑ CO 2 ↑ POP ↑ CO 2 ↑ TECH↑ CO 2 ↑ UP↑ CO 2 ↑
Panel B. The Positive relationship of Financial Inclusion/Financial Development with Co2 Emissions				
Le et al. (2020)	Asia (31 Countries)	2004-2014	The study investigate the financial inclusion -CO2 emissions nexus.	FI ↑ C02↑
Kayani et al. (2020)	10 Countries	1990-2016	They investigate the influence of development of financial system on Co2 emissions	FD↑ C02↑
Jiang and Ma (2019)	155 Countries	1990-2014	This study examine the relationship between financial development and carbon emissions	FD ↑CO 2 ↑
Lu (2018)	12 Asian countries	1993–2013	This study explore the casual impact of development of financial system on Co2 emissions	FD ↑CO 2 ↑
Cetin et al. (2018)	Turkey	1960-2013	This study examine the long and short run casual impact of development of financial system on CO2 emissions	FD ↑CO 2 ↑
Ali et al. (2019)	Developing economy	1971-2010	They examine the casual relationship between development of financial system and CO2 emissions	FD ↑CO 2 ↑
Panel C. The non-linear relationship between Financial Inclusion(Financial Development) and Co2 Emissions				
Renzhi and Baek (2020)	103 Countries	2004-2014	This study analyze the non-linear relationship of financial inclusion with carbon emission	Inverted U shaped relationship exist between Financial Inclusion C02(EKC exist)
Hung et al. (2018)	25 OECD countries	1971-2007	This study investigate the impact of development of financial system on CO2 emissions	FD inverted U-Shape CO 2(Supported)
Zaidi et al. (2019)	APEC countries	1990–2016	This study investigate the non-linear relationship of financial inclusion with carbon emission in EKC framework	FD inverted U-Shape CO 2(Supported)

Table 2. Description of Variables							
Variable	Symbol	Description	Mean	Std.Dev.	Min	Max	Obs
Carbon Emission	log(CO2)	It is calculated as CO2 in metric tons per capita	8.546	11.108	0.187	62.066	286
Financial inclusion(Proxy 01)	FI-1	It is measured as commercial banks' branches per 100,000 adults	14.165	11.45	2.327	71.21	286
Financial inclusion(Proxy 02)	FI-2	It is calculated as ATMs per 100,000 adults	41.531	53.18	0.011	288.6	286
Financial inclusion(Proxy 03)	FI-3	It measured as the outstanding deposits in banks divided by GDP	59.325	52.06	3.854	3.854	286
Financial inclusion(Proxy 04)	FI-4	It measured as the outstanding loans with banks divided by GDP	66.993	55.00	16.37	257.0	286
Trade openness	Log(TO)	It is calculated as export plus imports divided by GDP	103.97	68.547	23.922	437.327	286
Energy Consumption	Log(EC)	It is measured as energy consumption in Kg of oil Equivalent per capita	3122.33	4095.72	159.895	22120.0	286
Industry	Log (IND)	Measured as Industry (including construction) value added divided GDP	37.968	16.578	13.809	74.812	286

Table 3. Results of Bartlett test of Sphericity and Kaiser-Meyer-Olkin Measure of Sampling Adequacy.

	Bartlett test of sphericity			Kaiser-Meyer
	Chi-square	DF	p-value	
FI	630.58***	15	0.000	0.7100

represents the financial inclusion index

Table 4. Total variance explained

Component	Eigenvalues	% of Variance	Cumulative Variance %
1	2.4594	0.6148	0.6148
2	0.741919	0.1855	0.8003
3	0.687705	0.1719	0.9723
4	0.110979	0.0277	1.000

Table 5. Results from Cross-section independence tests.		
Panel A: Pesaran (2004)		
CO2	10.27***	0.000
FI	17.61***	0.000
TO	6.32***	0.000
EC	4.42***	0.000
IND	3.34***	0.000
Panel B: Pesaran (2015)		
CO2	12.878***	0.000
FI	5.502***	0.000
TO	59.742***	0.000
EC	59.778***	0.000
IND	59.766***	0.000

Note:*,**,*** denote statistical significance at the 10%, 5% and 1% level respectively.$Co2_{i,t}$ stands for log of carbon emissions, $FI_{i,t}$ represents the financial inclusion index, TO is trade openess, EC represents energy consumption, IND is industry

Table 6. Results for D-H granger causality test.

X → Y	CO2	FI	TO	EC	IND
CO2	-	×	×	√	√
FI	√	-	√	√	√
TO	√	√	-	×	×
EC	√	√	×	-	√
IND	√	√	√	√	-

$Co2_{i,t}$ stands for log of carbon emissions, $FI_{i,t}$ represents the financial inclusion index, TO is trade openess, EC represents energy consumption, IND is industry

Table 7. Panel unit root tests for stationarity.

	Panel A: Individual Intercept and Trend					Panel B: Individual Intercept				
	CO2	FI	TO	EC	IND	CO2	FI	TO	EC	IND
CIPS	-1.692	-1.3570	-1.946	-2.095	-2.905	-1.345	-1.334	-1.334	-1.530	-2.033
Breitung	0.3683	1.3670	-1.1748	0.1996	-0.890					
IPS	-2.0464***	-1.1903***	-3.3462***	-3.0001***	-3.5076***	1.7592	3.1528	-0.9838	0.4165	-1.4428
Fisher-ADF	10.2321***	2.0443***	4.8451***	2.1707***	1.7867***	1.7400***	-1.2202	-0.6592	-3832	0.0141
Fisher-PP	-1.653	-0.5198	6.4365***	4.5129***	3.920***	-2.3571	-0.8953	2.3376***	-0.204	4.9949**
Hadri	18.0272***	17.632***	18.0491***	17.2221***	19.0444***	5.8774***	5.7365***	6.3585***	5.8155***	5.6215**
LLC	-8.2961***	-6.342***	-5.7506***	-11.2083**	-12.640***	-3.7347***	-5.7506***	-6.342***	-1.9982***	-6.4398*
	ΔCO2	ΔFL	ΔTO	ΔEC	ΔIND	ΔCO2	ΔFL	ΔTO	ΔEC	ΔIND
CIPS	-2.669***	-2.670***	-2.891***	-2.813***	-3.733***	-2.468***	-2.082	-2.600***	-2.830***	-3.400
Breitung	-3.6838***	-5.7481***	-6.9126***	-3.1893***	-5.7239***					
IPS	-5.8043***	-4.773***	-5.9863***	-5.4863***	-6.4725***	-5.3463***	-5.6368***	-5.4308***	-5.6103***	-6.0434*
Fisher-ADF	13.8072***	1.7478***	23.6652***	5.1829***	5.4624***	11.5021***	0.901	9.0197***	0.5593	1.2346
Fisher-PP	15.2681***	10.5564***	15.435***	19.2849***	28.7813***	15.7315***	12.2693***	22.3802***	19.1135***	25.5263*
Hadri	24.6188***	28.0257***	27.8619***	23.9629***	29.472***	5.2258	6.0369	6.5038***	4.9387	6.9383
LLC	-20.608	-12.046	-21.11	-8.235***	13.75***	-12.64***	-11.41***	-17.35***	-11.07***	-7.777***

*,**,*** denote statistical significance at the 10%, 5% and 1% level respectively. $Co2_{i,t}$ stands for log of carbon emissions, $FI_{i,t}$ represents the financial inclusion index, TO is trade openess, EC represents energy consumption, IND is industry

Table 8. Panel Co-Integration Test Results for the Asia.					
Predroni (1999;2004) Panel Cointegeration Test					
Within-Dimension Test Statistics				Between-Dimension Test Statistics	
Panel v-Statistics	-1.418				
Panel rho-Statistics	3.682			Panel rho-Statistics	5.913
Panel PP-Statistics	-2.431**			Panel PP-Statistics	-4.768**
Panel ADP-Statistics	-1.854**			Panel ADP-Statistics	-3.732**
Kao (1999)Panel Cointegeration Test					
		Statistics	P-value		
Modified Dickey-Fuller t	-0.520***	0.030			
Dickey- Fuller t	-2.184***	0.015			
Augmented Dickey Fuller t	-1.657**	0.049			
Unadjusted Modified Dickey-Fuller t	-4.244***	0.000			
Unadjusted Dickey- Fuller t	-4.365***	0.000			
Westerlund(2005) cointegration Test					
Variance ratio		3.630***	0.000		

Note:*,**,*** denote statistical significance at the 10%, 5% and 1% level respectively.

Table 9. Pooled Mean Group (PMG) Results					
Dependent Variable					
	ΔCO2	ΔFL	ΔTO	ΔEC	Δ IND
Long-run					
CO2	-	-2.207	-0.019	0.937***	-0.087***
		(4.113)	(0.037)	(0.014)	(0.043)
FL	1.123***	-	0.029	-0.002	0.090***
	(0.116)		(0.022)	(0.001)	(0.010)
TO	0.254***	-16.33	-	0.019***	0.188**
	(0.061)	(21.56)		(0.005)	(0.018)
EC	0.455***	50.10*	-0.111***	-	-0.195**
	(0.188)	(65.62)	(0.041)		(0.055)
IND	0.470***	1.976	-1.009***	0.272***	-
	(0.157)	(5.515)	(0.044)	(0.018)	
Short-run					
Error Correction	-0.349***	-0.011***	-0.395***	-0.548***	-0.577***
	(0.094)	(0.004)	(0.118)	(0.070)	(0.081)
ΔCO2	-	-0.083	.0192	-0.459***	-0.004
		(0.158)	(0.117)	(0.083)	(0.393)
ΔFL	0.401*	-	0.144	0.006	0.104***
	(0.235)		(0.149)	(0.044)	(0.045)
ΔTO	-0.080	-0.395	-	-0.030	-0.121
	(0.136)	(0.309)		(0.073)	(0.080)
ΔEC	0.208	-0.157	-0.137	-	0.187***
	(0.294)	(0.353)	(0.198)		0.094
Δ IND	-0.209	0.175	(0.246)	0.120	-
	(0.248)	(0.319)	(0.205)	(0.122)	
Constant	0.497***	-3.517***	3.372***	2.801***	2.537***
	(0.1247)	(1.491)	(0.982)	(0.357)	(0.393)
Number of Observations	260.0	260.0	260.0	260.0	260.0
Number of Countries	26.00	26.00	26.00	26.00	26.00
Hausman Test	0.509	0.427	0.267	0.172	0.853

Standard errors are in parenthesis,*,**,*** denote statistical significance at the 10%, 5% and 1% level respectively .$Co2_{i,t}$ stands for log of carbon emissions, $FI_{i,t}$ represents the financial inclusion index, TO is trade openness, EC presents energy consumption, IND is industry.

Table 10: AB and BB Results

Difference GMM (AB)						System GMM (BB)				
Dependent Variable										
	CO2	FI	TO	EC	IND	CO2	FI	TO	EC	IND
L.CO2	0.532***					0.588***				
	(0.0601)					(0.070)				
L.FI		0.546***					0.968***			
		(0.0416)					(0.057)			
L.TO			0.361***					0.716***		
			(0.0372)					(0.053)		
L.EC				0.442***					0.859***	
				(0.054)					(0.019)	
L.IND					0.335***					0.738***
					(0.0327)					(0.0398)
FI	0.0571***		-0.0731***	0.0519***	-0.0307***	0.0321***		-0.0186	0.00662	-0.0373***
	(0.0171)		(0.0163)	(0.0083)	(0.0079)	(0.010)		(0.015)	(0.010)	(0.0058)
TO	0.0816***	0.113***		0.0131	0.0168	0.0469	0.167***		0.0980***	-0.0668***
	(0.0297)	(0.0313)		(0.0115)	(0.0117)	(0.029)	(0.040)		(0.014)	(0.0129)
EC	0.199***	0.243***	-0.0392		-0.00497	0.283***	0.101***	0.0794**		0.0585***
	(0.0709)	(0.0408)	(0.0369)		(0.017)	(0.069)	(0.028)	(0.037)		(0.0147)
IND	-0.156***	0.0508	0.101**	0.107***		0.160**	-0.279***	0.025	0.0437*	
	(0.0185)	(0.0481)	(0.040)	(0.022)		(0.0795)	(0.045)	(0.040)	(0.024)	
CO2		-0.00409	-0.0489***	0.147***	-0.0441***		-0.105***	-0.0579***	0.0997***	-0.00092
		(0.0171)	(0.016)	(0.011)	(0.007)		(0.024)	(0.016)	(0.012)	(0.00565)
Constant	2.155***	-2.431***	2.903***	3.334***	2.371***	-2.332***	-0.31	0.680**	0.321***	0.803***
	(0.482)	(0.469)	(0.366)	(0.403)	(0.233)	(0.379)	(0.269)	(0.270)	(0.107)	-0.165)
Wald chi2	531.16	346.09	456.63	1055.54	337.36	2931.61	22818.16	1677.82	18711.22	
Wald (Prob > chi2)	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	0.000	0.000	0.000
AR(1)	0.0167	0.0051	0.0235	0.0147	0.0022	0.0155	0.0018	0.0013	0.0193	0.0006
AR(2)	0.1477	0.1117	0.7722	0.6134	0.429	0.1398	0.942	0.136	0.4965	0.621
Hansen test (p value)	0.724	0.427	0.216	0.595	0.394	0.988	0.311	0.26	0.417	0.735
Observations	234	234	234	234	234	260	260	260	260	260
Number of id2	26	26	26	26	26	26	26	26	26	26

Standard errors are in parenthesis,*,**,*** denote statistical significance at the 10%, 5% and 1% level respectively. $Co2_{i,t}$ stands for log of carbon emissions, $FI_{i,t}$ represents the financial inclusion index, TO is trade openness,

EC presents energy consumption, IND is industry.

Table 11. Seemingly Unrelated Regression (SUR)					
Dependent Variable					
	CO2	FI	TO	EC	IND
CO2	-	0.617***	-0.409***	0.836***	0.157***
		(0.169)	(0.091)	(0.013)	(0.042)
FI	0.060***	-	-0.126***	0.026**	-0.228***
	(0.016)		(0.029)	(0.015)	(0.011)
TO	-0.163***	-0.520***	-	0.205***	-0.085***
	(0.036)	(0.117)		(0.031)	(0.031)
EC	1.087***	0.343**	0.668***	-	0.101***
	(0.017)	(0.195)	(0.101)		(0.048)
IND	0.226***	-3.399***	-0.307***	0.112***	-
	(0.060)	(0.157)	(0.111)	(0.053)	
Constant	-6.758***	11.21***	1.226***	4.933***	3.020***
	(0.219)	(1.292)	(0.701)	(0.223)	(0.305)
R-squared	0.9484	0.3437	0.0683	0.9483	0.528
Number of Observations	286	286	286	286	286
Number of Countries	26	26	26	26	26
Standard errors are in parenthesis,*,**,*** denote statistical significance at the 10%, 5% and 1% level respectively. $Co2_{i,t}$ stands for log of carbon emissions, $FI_{i,t}$ represents the financial inclusion index, TO is trade openness, EC represents energy consumption, IND is industry.					

Figures

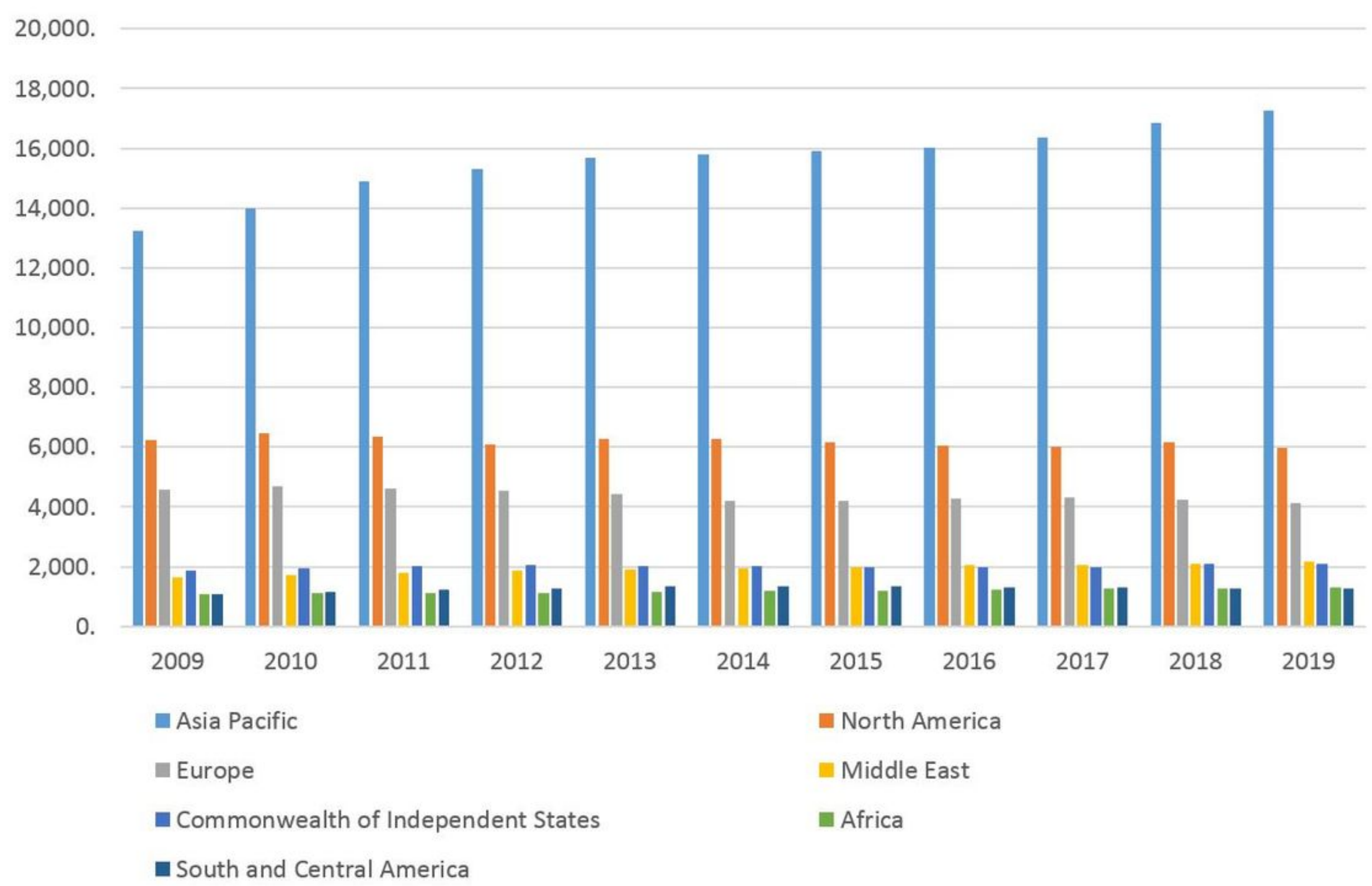

Figure 1

World carbon dioxide emissions: 2009-2019, by region (in million metric tons of carbon dioxide). Source: https://www.statista.com