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Investigating the role of financial development and technology innovation in climate change: evidence from emerging seven countries

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ABSTRACT

Amid raising ecological concerns, the role of sustainable financial system and emerging technologies have gained significant attention. And a relatively less attention has been given to these factors in emerging economies. Therefore, this study intends to investigate the effects of financial development and technology innovation on climate change (CO_2 emissions) in Emerging Seven countries over the period 1980–2020. In doing so, we have adopted a dynamic panel data model, that is, generalized method of moments, where climate change is given as an endogenous function of financial development and technology innovation by controlling the effects of economic growth, trade openness, population, industrialization, and urbanization. The overall results exhibit that the direct effect of financial development on climate change is adverse; however, the indirect effect through moderation of technology innovation is significantly positive. These outcomes imply that technology innovation is imperative to neutralize the negative consequences of financial development on climate change. These findings advocate financial reforms that effectively encourage and incentivize firms to embrace efficient and environmental friendly technologies in the financial sector.

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1. Introduction

Environmental deterioration and climate change are consequences of various economic activities to sustain higher economic growth (ECO_GRW). This growth has become a global challenge due to its substantial effects on human lives and global health (Ozturk et al., 2020; Razzaq et al., 2021; Sharif et al., 2020). In response, this has drawn the attention of the researchers to fully apprehend the dynamics of the relationship between the ECO_GRW and environmental issues (Khan et al., 2018;

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Uddin et al., 2017). ECO_GRW hinges on the strength of the financial sector (Shoaib et al., 2020). On the other hand, a strong financial sector ensures the effectiveness of funds available in the market to stimulate the organized and well-directed ECO_GRW (Ling et al., 2021; Safi et al., 2021). In this connection, Schumpeter (1911) has done the seminal work by establishing the link between financial development (F_DV) and ECO_GRW. Thereafter, plenty of studies revealed the relationship between F_DV and ECO_GRW (Shahbaz, 2009). Nevertheless, the cost associated with the ECO_GRW led by F_DV is a matter of environmental concern (Mikayilov et al., 2018). F_DV plays a significant role in stimulating growth but also has important ramifications for environmental quality (Ling et al., 2021).

In terms of how F_DV influences changes in the environment, recent literature has established a strong correlation between the F_DV and climate change (Maji et al., 2017; Shahbaz et al., 2013). Research findings are unequivocally contradictory in different countries around the world. Famous Environmental Kuznets Curve (EKC) also suggests that there is a non-linear inverted U-shaped relationship exist between F_DV and climate change (Grossman & Krueger, 1993). Empirical evidence suggested that F_DV is double edge sword that might stimulate CO2_EMS and as well as cause to decrease in CO2_EMS (Ziaei, 2015). So there is not a straightforward relationship exist between F_DV and climate change. Thus, surrounding variables should be taken into account while investigating the impact of F_DV on climate change (Godil et al., 2021; Sharif et al., 2019; Zameer et al., 2020). Previous literature focuses on the impact of F_DV led technological progress that influences climate change. This line of inquiry presents mixed results; some studies reported a negative link between F_DV and CO2_EMS via technological progress (Godil et al., 2021; Ling et al., 2021; Zameer et al., 2020), and some studies reported positive (Khan et al., 2018). This conundrum on financial development and climate change and the increasing rate of energy consumption raises serious environmental concerns (He et al., 2021). Thus, these issues need constant focus on the interdependent relationship among financial development, climate change, and technology innovations. Further, prior studies also highlighted that the link between economic development, energy innovation and climate change needs to be further examined (Gyamfi et al., 2021). Contrary to prior studies, using endogenous growth lens, we suggest indirect effect through moderation of technology innovation that nullifies the negative ramifications of financial development on climate change (An et al., 2021; Khan et al., 2021). It implies that technology innovation (TEC_INV) in the form of patents allows businesses to attract finances and simultaneously allows them to adopt advanced technologies that reduce the adverse effects of climate change (Chien et al., 2021; Lingyan et al., 2021; Razzaq, Wang, et al., 2021).

Studies investigating the impact of technological innovation on CO2_EMS in the developed economies through F_DV may not have relevance for emerging economies. Because large-scale businesses have already been shifted from developed economies towards emerging nations that significantly decreases the level of CO2_EMS in the developed economies. Several energy reports have also shown a significant decline in climate change in the developed world in the recent past (Gyamfi et al., 2021). In the case of emerging economies, an important quest is to achieve economic growth.

Studies indicated that E-7 countries face major challenges for sustainable economic growth (Destek & Sarkodie, 2019). E-7 countries are the panel of industrialized and emerging economies. It is important to investigate how they could neutralize the adverse effects of industrialization on environmental degradation. Emerging countries heavily rely on traditional energy such as coal and fossil oil which has environmental ramifications (Rodionova et al., 2017). The effect of financial development and technology innovation on climate change is compounded with the number of factors that require answer in emerging countries. Thus, succinct research is essential in the panel of E-7 countries to promote energy innovation to restrict environmental degradation. This leads us to investigate the issue in emerging countries E-7 (Emerging-7). This study investigates the Impact of F_DV on climate change in the presence of TEC_INV in the group E-7 countries covering the period from 1980 to 2020. E-7 countries include Brazil, China, Indonesia, India, Mexico, Russian Federation, and Turkey.

The primary reason to conduct this study in E-7 countries is that major emerging economies are held in this group, and over the past two decades, these economies have shown the phenomenal ECO_GRW along with significant environmental deterioration. One of the key reasons may be abundance of natural resources attracts businesses from all over the world. Thus, environmental issues are more important for the world in emerging economies. Moreover, the progress of financial markets in E-7 countries outperformed the markets of G-7 countries (Safi et al., 2021). Countries in E-7 utilize 40% of the world's energy consumption. Lastly, forecasted economic number for E-7 countries is much brighter than G-7.

This study contributes to the existing literature threefold. By employing the lens of endogenously growth theory, we have shown how TEC_INV can influence the relationship between F_DV and climate change by neutralizing the negative consequences for the environment. Prior studies have provided mixed findings. In this respect, using the Endogenous Growth theory, we may able to add up in the literature by highlighting one of the reasons of mix findings on financial development and climate changes (Baloch et al., 2021). Second, prior literature has an emphasis on the role of moderating variables. However, studies investigating the relationship between F_DV and climate change do not consider the moderating factors that may influence the relationship between F_DV and climate change. Prior studies suggested that surrounding variables should be considered while investigating the impact of F_DV on climate change (Godil et al., 2021). Lastly, this study is carried out in E-7 countries that have shown incredible growth in the last two decades. F_DV is on the fast track in these economies that creates environmental issues (Safi et al., 2021). The energy consumption ratio is on the higher side in E-7 countries in the world. Further, Foreign Investment inflows are also directed from all over the world in E-7 countries. All this shows the significance of reduction in CO2_EMS in E-7 countries; this further triggers the debate on the role of TEC_INV in climate change worldwide.

The remaining section of the study is as follows: Section 2 consists of theoretical and empirical literature. Section 3 comprises materials and methods, and section 4 presents results and discussion. The last section contains conclusion and implications.

2. Theoretical and empirical literature

Endogenous growth theory could be one of the indirect platforms that may be used to explain the phenomena between F_DV and climate change (Aghion et al., 1998). The focus of the endogenous theory for the ECO_GRW is on innovation and investments in human capital. Generally, theory supports the notion that internal factors are more important for an ECO_GRW rather than external factors. Economies utilize finance efficiently while directing or providing the industries through strong environmental and financial regulations that help stimulate the TEC_INV within the economy. Enhancement of TEC_INV capability through F_DV enhances the economic output and minimizes the required input via efficient energy use without compromising the environmental issues. TEC_INV required the funds that can be directed through important regulatory measures to enhance the innovative capability of the economy that then may be utilized to produce maximum output to stimulate the ECO_GRW without damaging the environment. Literature also suggested the eminent role of TEC_INV on climate change. However, without the provision of financing, it would be difficult for a country to adopt efficient technology and thereby ECO_GRW. This mechanism shows the link between F_DV and climate change by using endogenous growth theory. So, TEC_INV is an important aspect of the ECO_GRW; Literature has shown ample evidence that corroborates this line of arguments that technology-led growth does not create environmental issues and enhances the sustainable ECO_GRW.

Climate change (CO2_EMS) is a growing worldwide phenomenon. Need of the hour is to protect the world from such adverse changes that may threaten the life on the earth. Amid the sharp changes in the climate, sustainable economic development becomes a major challenge for the world, particularly in emerging economies (Zameer et al., 2020). Today economic development is evaluated in terms of its sustainability (Godil et al., 2021), a development that does not deteriorate the environment. Prior studies indicated that ECO_GRW led by F_DV may stimuli the climate change (Bekhet et al., 2017). F_DV has an anchoring role in climate change through economic development, it's triggered the ECO_GRW but reinforces environmental degradation as well (Shahbaz et al., 2013). Famous Environmental Kuznets Curve (EKC) suggested that there is non-linear inverted U-shaped relationship exist between F_DV and climate change (Grossman & Krueger, 1993). Similarly, Endogenous growth theory also suggests that the production factors are not the only source that influences the ECO_GRW, but the TEC_INV should also be taken into account while considering the impact of F_DV on climate change (Shoaib et al., 2020).

EKC and Endogenous growth theory implicitly focus on the type of economic measures a country is undertaking for economic growth. The degree of reliance on natural resources or technological resources for energy requirements to attain the ECO_GRW predicts the level of climate change within the economy (Ling et al., 2021). Thus, the type of energy resources utilized for economic output is a key element to determine climate change (An et al., 2021; Razzaq et al., 2021). Previous studies have provided mixed findings of the relationship between F_DV and climate change; some studies reported a negative relationship (Majeed & Luni, 2019; Zameer et al., 2019), and others suggested positive (Islam et al., 2013; Saidi & Mbarek, 2017;

Tamazian et al., 2009). The possible reason for these ambiguous findings may be embedded in the context of the utilization of available finance. It is important to know how the availability of finance is utilized to adopt energy measures for economic output.

Generally, developed economies rely on efficient energy sources for their economic output due to advancement factors and awareness about environmental pollution and its effects on human life. Developed economies have strong environmental regulations that restrict financiers to finance traditional sources of energy for economic activity. Such regulations provide incentives for financiers to finance eco-friendly technology for economic output that reduces CO_2 emission (Shoaib et al., 2020). Studies provide support for this notion that F_DV reduces the negative impact on climate change (Fernández et al., 2018; Shahbaz et al., 2013; 2016). Most of the studies confirm this line of arguments conducted in developed economies. In developed countries, strong environmental regulations exist that do not permit businesses to use pollution-intensive energy sources. Therefore, they rely on efficient energy sources eco-friendly green technologies for economic output. Awareness of environmental hazards is another important aspect that leads to the existence of strong environmental regulation in such economies. Thus, they rely on efficient energy resources for ECO_GRW that help them to mitigate environmental concerns in the form of less CO2_EMS.

In the contrary, some studies have found that F_DV deteriorate the environmental condition (Çoban & Topcu, 2013; Islam et al., 2013; Tang & Tan, 2014). Empirical evidence corroborates this stream of argumentation in emerging or developing economies. Ease of access to finance in an economy fastens the speed of production activities. Due to weak regulations, such economies do not care much about the environmental deterioration thus relies on pollution-intensive technologies for their ECO_GRW, for example, fossil oil, coal and natural gas. Moreover, stakeholders of the businesses such as customers, investors, and so on, are also not much aware of the harmful effects of such types of production activities. Moreover, in the priority ladder of the emerging economies, ECO_GRW comes before environmental issues. Because of poverty, scarce resources, technological shortcomings and lower research-based infrastructure, they rely on the traditional pollution intensive energy for economic output. Because they are in the developing phase, they are not equipped with the advanced level of efficient technologies. These economies also don't have the resources to generate or import such technology because of financing constraints (Razzaq, An, et al., 2021).

Additionally, financing for research and development activities are not easily available in third developing countries rather than tangible investment financing. One of the major reasons for the non-availability of financing for research related activities is collateral. Financial regulations of the emerging economies are also not comparable to developed economies along with financial infrastructure. These findings are corroborated in many studies (Majeed & Tauqir, 2020; Shahzad et al., 2021; Zhang, 2011). Likewise, some studies suggest that F_DV may be helpful to improve the environment through the provision of flexible planning schedules and economies of scale but it may also harm the sustainable environment by allowing new entrants in pollution intensive industries by providing a cheap source of financing (Cole et al., 2005).

Employing the latest endogenous growth theory, incorporating the moderating effects of technology innovation into the market function model is an important aspect to explain the major factors that influence the environment (Rafique et al., 2020). The implication is that effective utilization of financial development that leads to Technology innovation that in turn, significantly reduces the adverse changes in the climate in Emerging Markets. Endogenous growth theory suggests that the production factors are not the only source that influences the ECO_GRW, but the TEC_INV should also be taken into account while considering the impact of F_DV on climate change through the adoption of efficient technology sources. TEC_INV is imperative to mitigate the negative effects of F_DV on environment, particularly in developing economies (Shoaib et al., 2020). In recent times, the importance of TEC_INV in climate change is getting attention of the researchers (Godil et al., 2021). TEC_INV facilitates industry to reach out efficient energy sources instead of conventional one, such as fossil oil and natural gas. This enhances the efficiency of manufacturing procedures by minimizing inputs and maximizing output with a reduced level of CO2_EMS. Empirical evidence on the role of technology in climate change is also evident. For instance, Mensah et al. (2018) carried out in 28 OECD countries, reinforces that ECO_GRW triggered CO2_EMS but an increase in R&D activity significantly reduces CO2_EMS. They highlighted the importance of TEC_INV to protect the environment. Liobikienė and Butkus (2019) also corroborated that how financial dissemination may be helpful in reducing environmental degradation. TEC_INV has an imperative role in decreasing environmental degradation (Talbi (2017). Samargandi (2017) found the importance of TEC_INV in the manufacturing industry and its mitigating impact on CO2_EMS. Similar findings are presented by Yii and Geetha (2017) in Malaysia. These studies investigated the impact of communication technology on the environment and found that communication technology improves environmental quality (Al-Mulali et al., 2015; Ozcan & Apergis, 2018).

Technology innovation could be an important source to limit the adverse effects of financial development on climate change (Baloch et al., 2021; Mensah et al., 2019). Similarly, studies reveal that patents decline the negative impact of financial development on climate changes (Adebayo et al., 2021; Mensah et al., 2019). On this backdrop, the role of TEC_INV becomes prominent in emerging economies because of higher level CO2_EMS as compared to developed economies. The role of technological advancement is more clearly born in the emerging economies because the influx of TEC_INV effectively declines the level of environmental degradation (Bekun et al., 2021). Lv and Xu (2018) found the declining impact of advances in communication technologies on CO2_EMS through reduction of air pollution in emerging economies. Effective utilization of smart communication technology, such as internet/mobile, restricts outdoor activities reduces the energy demand, thereby CO2_EMS. Ozcan and Apergis (2018) carried out a study on the same issue in emerging economies and revealed that the adoption of communication technology significantly reduces the environmental degradation. Similar findings are suggested by Zhang and Liu (2015) for China.

A large part of the foreign direct inflows worldwide is directed towards emerging economies, particularly in E-7 countries, due to different comparative advantages. To draw the world's attention, such emerging economies enhance the TEC_INV through making innovation in digital business to attract the FDI from the developed countries to further acerbate the level of FDI inflows (Solarin et al., 2021). Particularly, China and India have made strong strides in Technology advancement that may also encourage other countries that are using traditional technology in their respective Industries. This implies that technology inflows are endogenously causes improvement of the F_DV and decrease in climate change simultaneously. On the basis of the above arguments, we suggest that economic growth without appropriate allocation of funds for efficient energy sources and weak environmental and financial regulation leads to a positive association between financial development and climate change. However, the moderating role of TEC_INV becomes more prominent to deal with this menace. An increase in financial development with the increasing rate of TEC_INV neutralizes the negative effect of financial development on climate changes in E-7 countries (Baloch et al., 2021; Gyamfi et al., 2021).

3. Materials and methods

This research study analyzed the impact of financing on climate change. In order to achieve said objective, the study was conducted among E-7 emerging economies such as Brazil, China, Indonesia, India, Mexico, Russian Federation, and Turkey. These countries are selected because they are developing countries and contribute significantly to the global economy. In this study, data was confined to the period of 1980–2020 and collected from World Development indicators in respect to CO2_EMS, F_DV, industrialization, trade openness, urbanization, ECO_GRW and population, while the data for TEC_INV is taken from British petroleum website. Table 1 describes the detail of variables with justification used in this study.

Usually, three regression techniques are utilized to estimate panel data; ordinary least square (OLS), random effect model (REM) and fixed effect model (FEM). The OLS model is called as constant coefficient model and is mostly used for estimating unknown parameters in a linear regression model. This model assumed that the intercept and coefficient are homogenous for all firms. In general, ordinary least square regression model ignores the individual and time effects. On the other hand, the REM and FEM are used to determine the relationships within or between each cross section (Baltagi, 2008). The FEM allows control for unobserved heterogeneity and is unable to resolve endogeneity issues (Mundlak, 1961). Therefore, the study used the generalized method of moments (GMM) technique to address the endogeneity and reverse causality between model variables. This method is called as dynamic panel data technique as this method not only resolve the endogeneity problem but also overcome unobserved heterogeneity respectively. Initially, we applied some preliminary tests and subsequently applied dynamic GMM to estimate long-run parameters.

3.1. Descriptive statistics

Descriptive measurements are brief expressive coefficients that summarize a given information set, which can either illustrate the entire population or a sample of it. In descriptive statistics, we can determine the measure of deviation and measures of

Table 1. Detail and Justification of variables.

Variable name	Variable Nature	Unit of measurement	Justification of Variables
Carbon Emissions (CO2_EMS)	Dependent Variable	Metric tons per capita	(Chen & Lei, 2018; Godil et al., 2020; Shahbaz et al., 2013; Shoaib et al., 2020; Tamazian et al., 2009)
Financial Development (F_DV)	Independent Variable	Domestic credit provided by financial sector (% of GDP)	(Chen & Lei, 2018; Godil et al., 2020; Law et al., 2018; Shoaib et al., 2020; Zameer et al., 2020)
Technology Innovation (TEC_INV)	Moderating Variable	Total patent applications	(Bottazzi & Peri, 2003; Chen & Lei, 2018; Law et al., 2018; Tebaldi & Elmslie, 2013; Weina et al., 2016)
Economic Growth (ECO_GRW)	Control Variable	GDP per capita growth (annual %)	(Godil et al., 2020; Shoaib et al., 2020; Tamazian et al., 2009)
Industrialization (IND)	Control Variable	Industry share as a % of GDP	(Majeed & Tauqir, 2020; Tamazian et al., 2009; Xu & Lin, 2015)
Trade Openness (TOP)	Control Variable	Import + export (% of GDP)	(Fang et al., 2020; Law et al., 2018; Shahbaz et al., 2013; Zameer et al., 2020)
Urbanization (URB)	Control Variable	% of total population	(Fang et al., 2020; Majeed & Tauqir, 2020)
Population (POP)	Control Variable	Population growth (annual %)	(Bottazzi & Peri, 2003; Chen & Lei, 2018; Shahbaz et al., 2018)

Source: Author calculation.

central tendency. The measures of deviation comprise minimum value, maximum value, and standard deviation etc. Whereas the measures of central tendency include mean value, median value, and mode value, respectively. The descriptive statistics describes and summarizes the behaviour of variables used in the study.

3.2. Multicollinearity test

Multicollinearity could be a measurable marvel in which two or more illustrative factors in a multiple regression model are profoundly correlated (Greene, 2003). The problem of multicollinearity is observed when there is a culminate perfect linear association between two or more variables (Gujarati & Porter, 2009; Hamilton, 2012). In case the bivariate correlation coefficient between combined indicator factors is high, surpassing 0.80, there's an issue of multicollinearity. Put in an unexpected way, explanatory factors ought to not correlate too high since in case so, the assessed parameter become untrustworthy and the indicators become less important (Field, 2009). One of the techniques to detect multicollinearity is the construction of correlation matrix. The correlation matrix of variables shows the correlation of explanatory variables. As a rule of thumb, Field (2009) states that correlation above 0.8 is a cause for concern. It provides both the direction and the strength of a relationship.

3.3. Heteroscedasticity test

The words homoscedasticity and heteroscedasticity have a Greek-origin and refer to the equality and inequality of variance of the error term in regression equations (Hair et al., 2006). In regression, the random variables are identically and independently distributed which means that these variables have some variance for all the observations in a given data set. This phenomenon is called homoscedasticity. On the off chance that they are not, it causes genuine issues for the estimates and must be adjusted for the research to get reliable estimates. Heteroscedasticity may form because of incorrect model specifications or wrong data transformation. Therefore, the variance of the dependent variable changes (Hair et al., 2006). In reality, heteroscedasticity may arise when various observations have diverse error variances. To detect the heteroscedasticity of the residual variance, Breusch-Pagan or Cook-Weisberg test was applied in each of the regression models. The criteria is that if the p-value is less than 0.05 percent it means that there is heteroscedasticity issue in the variance of dependent variables; therefore the model should be regressed using the least square estimator with robust standard regression.

3.4. Generalized method of moments (GMM)

The GMM has ended up an imperative estimation approach in different areas of applied economics and finance. According to Pikas, the GMM methodology covers the dimensions of both time series and cross-sectional estimations. GMM is also called as dynamic model as this model have the features to elucidate the issue of endogeneity as well as it offers more effective instruments that control for endogeneity (Arellano & Bond, 1991). This procedure of GMM is flexible because it only requires a few assumptions about moment conditions. The motivation for using GMM is because of three reasons. The first reason is that it controls the country-specific effect. The second reason is that come macroeconomic factors in the model, such as F_DV, trade openness, and ECO_GRW are assumed to be endogenous. Third, the presence of the lagged dependent variable in the model gives rise to autocorrelation problems. For the first problem, Arellano and Bond (1991) propose transforming the level equation into first differences to eradicate the unseen country-specific effect. GMM is applied when the descriptive factors are not stringently exogenous indeed after controlling for an unnoticed effect. The consistency of the GMM estimator depends on the cogency of the instrument. In order to resolve this issue, the study used two specification tests recommended by Arellano and Bond (1991). The first test is called the Sargan/Hansen test. This test will check the overall validity and reliability of the instruments by determining some momentum conditions as specified in the estimation process. The second test determines the absence of the serial correlation of the error terms using the first and second order serial correlation test.

The first-order serial correlation, signified as AR1 in the differential residual, it is due to the first difference of models and second-order serial correlation, difference residual denoted as AR2. GMM is well suited for obtaining efficient estimators that account for the serial correlation (Arellano & Bond, 1991). The empirical model for this study is as follows;

$$\begin{aligned}\Delta \mathrm{CO2\_EMS_{it}} &= \beta_0 + \beta_1 \mathrm{F\_DV_{it}} + \beta_2 \mathrm{TEC\_INV_{it}} + \beta_3 (\mathrm{F\_DV} * \mathrm{TEC\_INV})_{it} \\ &\quad + \beta_4 \mathrm{ECO\_GRW_{it}} + \beta_5 \mathrm{TOP_{it}} + \beta_6 IND_{it} + \beta_7 \mathrm{URB_{it}} \\ &\quad + \beta_8 \mathrm{POP_{it}} + \varepsilon_{it}\end{aligned} \tag{1}$$

Table 2. Descriptive statistics.

Variable	Observation	Mean value	Standard deviation	Minimum value	Maximum value
CO2_EMS	287	4.4593	5.3754	0.4492	26.8992
F_DV	287	57.9923	38.0213	8.8214	212.9187
TEC_INV	287	44811.02	190672.4	5.000	1393815
ECO_GRW	287	2.6929	4.8066	−14.5684	13.6383
TOP	287	41.1145	17.2429	12.0086	110.5771
IND	287	32.3867	9.2353	11.3991	48.0607
POP	287	1.2940	0.6806	−0.4600	2.3974
URB	287	56.7065	20.6771	19.3580	87.0730

Note: The Table 2 reports descriptive statistics summary based on overall dataset of E7 countries. The dependent variable is carbon dioxide emissions (CO2_EMS). The independent variable is financial development (F_DV), the moderating variable used in the study is technology innovation (TEC_INV), and the control variables are economic growth (ECO_GRW), trade openness (TOP), industrialization (IND), population (POP) and urbanization (URB).
Source: Author calculation.

where $CO2_{it}$ is carbon dioxide emissions (climate change) in country i at time t; $F_{DV}it$ is financial development in country i at time t; $TEC_{INV}it$ is technology innovation in country i at time t; $ECO_{GRW}it$ is economic growth in country i at time t; TOP_{it} is trade openness in country i at time t; IND_{it} is industrialization in country i at time t; URB_{it} is urbanization in country i at time t; POP_{it} is population in country i at time t; μ_i is the time invariant fixed effect, μ_t is the firm invariant time specific effect and ε_{it} is disturbance term.

4. Results and discussion

4.1. Descriptive Statistics

The descriptive statistics are shown in Table 2, which depicts the mean, standard deviation, and minimum, maximum and of all the variables. CO2_EMS varies from 0.4492 to 26.8992, with a mean value of 4.4593 and standard deviation of 5.3754, respectively. The mean value of financial development (F_DV) is 57.9923, ranging from 8.8214 to 212.9187 with a standard deviation of 57.9923. The technology innovation (TEC_INV) varies from 5.0000 to 1393815, with a mean value of 44811.02 and a standard deviation of 190672.4, respectively. The mean value of the product of financial development with technology innovation (F_DV* TEC_INV) is 6831564, ranging from 44.1073 to 2.53E+08 with a standard deviation of 3.37E+07. Economic growth (ECO_GRW) varies from −14.5684 to 13.6383 with a mean value of 2.6929 and standard deviation of 4.8066, respectively. Trade openness (TOP) varies from 12.0086 to 110.5771, with a mean value of 41.1145 and a standard deviation of 17.2429, respectively. The mean value of industrialization (IND) is 32.3867, ranging from 11.3991 to 48.0607 with a standard deviation of 9.2353. Population (POP) varies from −0.4600 to 2.3974, with a mean value of 1.2940 and a standard deviation of 0.6806. Urbanization (URB) varies from 19.358 to 87.073 with a mean value of 56.7065 and standard deviation of 20.6771, respectively.

4.2. Correlation analysis

Table 3 provides a summary of correlation matrix of financial development with climate change on overall dataset of E-7 emerging economies. The table shows that the

Table 3. Correlation matrix.

	CO2_EMS	F_DV	TEC_INV	FDV* TEC_INV	ECO_GRW	TOP	IND	POP	URB
CO2_EMS	1								
F_DV	0.090	1							
TEC_INV	−0.141**	0.590***	1						
FDV* TEC_INV	−0.103*	0.580***	0.597***	1					
ECO_GRW	−0.370***	0.220***	0.143**	0.143**	1				
TOP	−0.200***	−0.050	0.009	−0.004	−0.044	1			
IND	0.308***	0.040	0.203***	0.182***	0.214***	0.371***	1		
POP	0.620***	−0.270***	−0.279***	−0.243***	0.025	−0.384***	−0.260***	1	
URB	0.394***	0.110*	0.003	−0.002	−0.448***	0.185***	−0.425***	−0.339***	1

Note: CO2_EMS = carbon dioxide emissions, F_DV = financial development, TEC_INV = technology innovation, FDV* TEC_INV = product of financial development and technology innovation, ECO_GRW = economic growth, TOP = trade openness, IND = industrialization, POP = population, and URB = urbanization. The p-values shown in parentheses, that is, ***, **, and * denotes significance at 1%, 5% and 10% levels, respectively.
Source: Author calculation.

correlation coefficients of CO2_EMS with technology innovation (TEC_INV), product of financial development and technology innovation (FDV* TEC_INV), trade openness (TOP), industrialization (IND) and urbanization (URB) remained positively significant significance at 1%, 5% and 10% levels, respectively. Whereas correlation coefficients are negatively significant for (ECO_GRW) and population (POP) at 1% level of significance.

4.3. Heteroskedasticity test

In order to determine the homoskedasticity of the residual variance, Breusch-Pagan or Cook-Weisberg test was applied. The tested models in Table 4 indicate that there is no heteroskedasticity issue in variance of dependent variables.

4.4. GMM results

From Table 5, the GMM results revealed that the coefficient of F_DV is positively and is significantly related to the CO2_EMS. The coefficient value of F_DV is 0.0105 at 1% level of significance, which indicate that every 1% increase in F_DV leads to a 1.05% increase in CO2_EMS. The positive sign of the coefficient reflects that the current F_DV has stimulated the development of E-7 economies but brought carbon emissions. Likewise, the effect of TEC_INV is negatively discernible with CO2_EMS, and the results are significant at 1% level of significance with a coefficient value of 0.0032, implying that a 1% increase in TEC_INV leads to 0.322% decline in CO2_EMS. The findings reveal a significant negative association for the moderating variable TEC_INV (product of financial development and TEC_INV) with climate change with the coefficient value of −0.0016% at 1% level of significance.

The relationship between ECO_GRW and CO2_EMS exhibit a high significant negative relationship with the coefficient value of −0.0601 at 1% level of significance. In case of the association between the trade openness and CO2_EMS, the findings are found to be negatively and highly significant at 1% level of significance with the coefficient value of −0.0306. Similarly, the coefficient value of urbanization is 0.1732, and the findings reveal a significant positive association between urbanization with CO2_EMS. In case of the association between the industrialization and CO2_EMS,

Table 4. Heteroskedasticity test result.

Breusch-Pagan/Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of CO2
chi2(1) = 160.44
Prob > chi2 = 0.0000

Source: Author calculation.

Table 5. GMM results.

Variables	Coefficients	Standard errors
F_DV	0.010***	(0.00203)
TEC_INV	−0.032***	(0.00003)
F_DV* TEC_INV	−0.016***	(0.00001)
ECO_GRW	−0.060***	(0.00977)
TOP	−0.0306***	(0.00356)
IND	0.3945***	(0.01115)
POP	2.6534***	(0.17992)
URB	0.1732***	(0.00998)
Constant	−21.071***	(0.75331)
AR(1)	0.803	
AR(2)	0.882	
Sargan Test	1.000	
Prob(F-stat.)	0.000	
Countries	07	
Observation	287	

Note: CO2_EMS = carbon dioxide emissions, F_DV = financial development, TEC_INV = technology innovation, FDV* TEC_INV = product of financial development and technology innovation, ECO_GRW = economic growth, TOP = trade openness, IND = industrialization, POP = population, and URB = urbanization. The tests for serial autocorrelation denoted as AR1 and AR2. The Sargan test identifying that the instrument are healthier in estimating the dynamic model. The p-values shown in parentheses, that is, ***, **, and * denotes significance at 1%, 5% and 10% levels, respectively.
Source: Author calculation.

the coefficient value is 0.3945 and the findings are found to be positive and highly significant at 1% level of significance. The population as a control variable also shows a highly significant positive relationship with CO2_EMS at 1% level of significance with the coefficient value of 2.6534.

The findings of this research study revealed that there is a positive relationship between F_DV and CO2_EMS. These findings indicate that increase in F_DV causes to increase CO2_EMS intensity and support the findings of (Bello & Abimbola, 2010; Chen & Lei, 2018; Fang et al., 2020; Jalil & Feridun, 2011; Shoaib et al., 2020; Tsaurai, 2019). For TEC_INV the findings indicate that green technology is meant to play a central role in reducing the environmental effect of CO2_EMS and of other pollutants and considerably affect environmental performance (Gilli et al., 2014; Weina et al., 2016). Wang et al. (2012) found that innovations that are oriented toward carbon-free technologies can significantly help lower CO_2 levels. Likewise, Fernández et al. (2018), which has indicated that ECO_GRW achieved through technological progress would result in reducing environmental pollution. Ganda (2019) noted that spending on R&D has an inverse relation with carbon emissions.

Cheng et al. (2018) also found similar thoughts and indicated that technical progress significantly influences carbon intensity. These findings are in line with the preceding studies Álvarez-Herránz et al. (2017), Chen and Lei (2018), Dauda et al. (2019), Fernández et al. (2018), Muhammad Shahbaz et al. (2020) and Zameer et al. (2020). In addition, the findings for moderation variable TEC_INV (product of financial development and TEC_INV) with CO2_EMS shows a negative relationship. The endogenous growth theory supports the argument, as the theory considers that technological progress improves the capability of a nation to replace the polluting resources with other environmentally friendly resources (Zameer et al., 2020). First, F_DV, which has structural and technological effects on carbon emissions reduction, helps to reduce emissions (Destek & Sarkodie, 2019). With the gradual improvement of a country's financial system, the government can channel funds to relevant industries, optimize industrial mix and reduce carbon emissions through providing green credit funds for low-pollution enterprises (Masih et al., 2009; Zhang, 2018).

Tamazian et al. (2009) point out that a sound financial market system can reduce financing costs and streamline financing channels, which helps companies to purchase green equipment and undertake green technology R&D. The results are supported by the findings of D. I. Godil et al. (2020), Yii and Geetha (2017), Yusuf et al. (2019). Likewise, ECO_GRW shows a significant negative relationship with CO2_EMS. Tamazian et al. (2009) determined that higher degree of ECO_GRW decreases the environmental degradation and significantly causes to decline the carbon emissions (Shoaib et al., 2020). The developed and strong financial system of a country enhances ECO_GRW and reduces CO2_EMS (Frankel & Romer, 1999). They also suggested that higher F_DV boost R&D activities, which accelerate ECO_GRW and reduces environmental degradation. The studies conducted to examine the association between the ECO_GRW and CO2_EMS exhibiting negative relationship (Beckerman, 1992; Dutt, 2009; Frankel & Romer, 1999; Qasim et al., 2015; Shoaib et al., 2020). The researcher's findings depicted that higher proportion of ECO_GRW is associated with greater reduction in CO2_EMS. For trade openness the results implies that trade openness declines energy pollutants and improves environmental quality. These results are consistent to the prior studies (Chen & Lei, 2018; Muhammad Shahbaz et al., 2013). There is a significant positive relationship between urbanization and CO2_EMS. These findings can be interpreted that increase in urbanization increases CO2_EMS, This is mainly due to the fact that urbanization causes infrastructure development and improvement in residents' lives and causes environmental pollution in the long run (Fang et al., 2020). These results are consistent to the prior studies (Fang et al., 2020). The findings for industrialization and CO2_EMS is positive and shows that at early stages of industrialization there is the large requirement for energy consumption and low energy-saving technology causes increase in CO2_EMS. These results are consistent to the prior study (Sahoo & Sethi, 2020; Tamazian et al., 2009; Xu & Lin, 2015; Yazdi & Shakouri, 2018; Zhu et al., 2017). Lastly the variable population shows significant positive relationship with CO2_EMS and the findings indicated that population size was the most important driving force of carbon emissions. The results are supported by the findings of Chen and Lei (2018), Jorgenson and Clark (2010), and Yu et al. (2018).

5. Conclusion and policy implications

In the context of the E-7 emerging economies, this study investigates the effects of financing on climate change. In so doing, we focus on the impact of F_DV mediated by TEC_INV on climate change (CO2_EMS) and also incorporate the effect of some control variables like ECO_GRW, trade openness, population, industrialization, and urbanization in the carbon emissions function for the E-7 economy for the period 1980–2020. For the empirical purpose, the study applied some standard diagnostic tests in order to check the properties of data and then the study applied GMM technique in order to check the relationship between said variables. In the light of our empirical results, we can hereby conclude the presence of significant relationship between F_DVs on climate change moderated by TEC_INV. More specifically, we conclude that in E-7 emerging economies, an increase in TEC_INV improves environmental quality by reducing carbon emissions. TEC_INV was also found to be an important factor in reducing carbon emissions.

The findings from this research study indicate that the reduction in CO2_EMS can also be accomplished through investment in TEC_INV, that is, in case the nation follows technological innovation in terms of green technology, it can offer assistance to the firms to improve their efficiency in terms of energy usage. The findings of this study suggest some important policy recommendations. The countries should develop and improve policies for trade openness to encourage ECO_GRO and a high level of TEC_INV, which will ultimately help reduce environmental degradation. Likewise, E-7 countries should use advanced technologies and equipment in their industries and develop strategies to reduce CO2_EMS. As every country is trying to increase urbanization and industrialization to increase its economic growth, this will also affect the environment badly. In order to overcome the negative effects on the environment, the findings suggested that all countries, irrespective of their income level, must develop green and sustainable urbanization and industrialization policies to conserve the global environment. The findings of this research study suggested that with a better financial system, more finances ought to be invested in clean energy projects. The endogenous growth theory underpins the contention of the noteworthy effect of technological progress on ECO_GRW and natural contamination. This theory considers that technological progress develops a country’s capabilities to supplant the contaminating resources with other environment-friendly resources (Zameer et al., 2020). As F_DV showed a significant negative relationship with climate change, it is further suggested that the E-7 economies government should reassure more usage of those credit approaches that ensure the loans taken by the financial sector that must be utilized towards the environmentally friendly projects that diminish CO2_EMS.

5.1. Limitations and future direction

This study has some limitations which can be considered for future research. First, the time span and the sample size need to be extended. Second, some other proxies may be used for financial development, technology innovation in order to compare the result. Third, Still, there are more than one variable other than TEC_INV that moderate the financing-climate prevention relationship, such as eco-innovation, R&D, and green technology and so on. Finally, this study used CO_EMS as a dependent variable; future studies may disaggregate energy consumption into renewable energy and non-renewable energy source, respectively.

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