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# Financial Development, Institutional Quality, and the Influence of Various Environmental Factors on Carbon Dioxide Emissions: Exploring the Nexus in China

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Carbon dioxide ($CO_2$) emissions have been the key source of extreme environmental degradation and have an adverse impact on climate and human activities. Although a large number of studies have explored the determinants of $CO_2$ emissions, the role of institutional quality has not been fully studied. Our study contributes to the existing literature by examining the influence of financial development, institutional quality, foreign direct investment, trade openness, urbanization, and renewable energy consumption on $CO_2$ emissions over the period 1996–2020 by utilizing the dynamic autoregressive distributed lag simulations. The empirical findings of the study indicate that the indicators of governance, trade, financial development, and renewable energy consumption adversely affect $CO_2$ emissions, while urbanization and foreign direct investment contribute to environmental degradation. The empirical results of this study indicate that in order to mitigate environmental degradation and to achieve environmental sustainability, the government should establish consistency between environmental and economic policies. Moreover, in order to achieve low carbon emissions and sustainable development, countries need viable financial institutions that focus on green growth by promoting clean production process strategies to ensure the reduction of $CO_2$ emissions.

**Keywords: financial development, $CO_2$ emissions, institutional quality, renewable energy, sustainability development**



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## 1 INTRODUCTION

Global warming is a serious and challenging environmental issue of the contemporary period. Scientists unanimously believe that carbon emissions from the burning of fossil fuels and greenhouse gas emissions are warming the atmosphere around the globe (Intergovernmental Panel on Climate Change (IPCC), 2007). In the past few decades, greenhouse gas emissions, mainly, carbon dioxide emissions, have led to global warming, which leads to changes in global climate (Seetanah et al., 2018; Farooq et al., 2019; Ghazouani et al., 2020; Shahzad et al., 2020; Fatima et al., 2021a; Rafique et al., 2021; Shahzad et al., 2021c). Environmental degradation has become one of the world's major issues that may adversely affect the health of human beings (Zhang et al., 2018; Mardani et al., 2019;

Adedoyin et al., 2020; Shahzad et al., 2021b; Murshed et al., 2021) and sustainable economic performance of countries (Amin et al., 2020b; Ding et al., 2020; Amin and Dogan, 2021; Yousaf et al., 2021; Sharma et al., 2021); this is the reason the issue of environmental degradation has attracted enormous attention from researchers and policymakers in the recent era (Destek and Sarkodie, 2019). It is widely recognized that environmental degradation arises from greenhouse gas (GHG) emissions (Amin et al., 2020a), which contribute to global warming (Atasoy, 2017).

China has experienced rapid economic development in recent decades, and this rapid development has contributed to environmental degradation in the country (Jalil and Feridun, 2011). According to the Carbon Brief calculations, China's $CO_2$ emission reached 10 billion tons in 2018, whereas the total carbon emissions of the United States and the European Union countries were 5.4 billion tons and 3.5 billion tons, respectively, in the same year. Recently, China became the world's largest CO emitter and energy-consuming country (Al-Arkawaz, 2018). Its energy consumption per unit of GDP is twice the world average, and per capita $CO_2$ emissions have increased by 40% in the world. The growth rate of carbon ($CO_2$) emissions in China has risen more than 11% per annum (Auffhammer and Carson, 2008). Hence, this rapid increase in $CO_2$ in the last couple of years might result in degradation of the Chinese economy (Ang, 2009; Jalil and Mahmud, 2009). In order to understand the key determinants of China's carbon emissions precisely, a lot of research scholars investigated the nexus among energy consumption, economic growth, population, energy, as well as the industrial structure and carbon emissions (Auffhammer and Carson, 2008; Lin and Jiang, 2009; Zhang et al., 2011; Dietzenbacher et al., 2012; Du et al., 2012; Zhou et al., 2013; Wang et al., 2014). However, the nexus between financial development and energy consumption is hardly explored, particularly in the case of China (Xiong and Qi, 2018) despite the Chinese economy having gone through a high rate of economic growth at the regional and international levels and rapid financial development in the recent two and a half decades (Jalil and Ma, 2008; Jalil et al., 2010).

Two empirical research studies, Jalil and Feridun (2011) and Zhang (2011), explored the impact of financial development on carbon emissions, particularly in the case of China (Xiong and Qi, 2018). Jalil and Feridun (2011) investigated the long-run impact of financial development on carbon emissions and concluded that financial development reduces carbon emissions in the long run. The study by Zhang (2011) investigated the nexus between financial development and carbon emissions; the study concluded that financial development is the key driver of carbon emission in the case of China. Another recent study by Xiong and Qi (2018) explored the nexus between financial development and carbon emissions in China at the provincial level; they concluded that the effect of technology and structure on financial development surpasses decreases carbon emissions per capita. An empirical study by Tamazian and Rao (2010) confirmed the importance of both financial development and institutional quality for carbon emission performance, but this study claims that financial liberalization might harm environmental quality if the institutional framework is not strong enough. Another study by Claessens and Feijen (2007) confirmed that financial development can significantly reduce environmental problems through improved governance. Also, a study by Frankel and Romer (1999) confirmed that financial liberalization may drive FDI inflows, which, in turn, can hasten quick growth and, thus, harm environmental quality and increase carbon emissions. Also, renewable energy is the most efficient way to protect environmental quality (Bhattacharya et al., 2016; Sharif et al., 2019; Bashir et al., 2020; Bashir et al., 2021; Doğan et al., 2021; Fatima et al., 2021b; Shahzad et al., 2021a; Wang et al., 2021).

The practical significance of financial development in terms of economic growth and its long-term effects on environmental degradation is quite interesting to explore due to several reasons (Jalil and Feridun, 2011). Although the empirical studies, such as Zhang (2011) and Jalil and Feridun (2011), are quite interesting and provide valuable insight into understanding the nexus between financial development and carbon emissions at the macroeconomic level, particularly in the case of China, these studies also suffer from significant shortcomings in the form of missing notable variables such as institutional quality, FDI inflows, and interactive proxy variables (TRADE*FD). Another recent study by Xiong and Qi (2018) also provides useful insight into comprehending the linkage between financial development and carbon emissions by incorporating interesting key notable variables such as urbanization, research and development ratio, and energy consumption by applying STIRPAT panel data methodology, but this study also suffers from a major limitation that it narrowly focused only at the Chinese provincial level or industrial level.[1] There are few empirical panel data studies that analyzed the impact of financial development on carbon emissions. However, it is widely recognized that any potential inference drawn from these cross-country studies provides only a general understanding of the linkage between the variables, and thus, these studies are unable to offer much guidance on policy implications for each country (Stern et al., 1996; Lindmark, 2002; Ang, 2008). Hence, the aim of this research was to investigate particularly the impact of financial development on carbon emissions in the case of China.

Our empirical research study contributes to the existing research literature in different contexts. First, we extend the prior works of Zhang (2011) and Jalil and Feridun (2011) but with significant differences. Limited to our knowledge, this is the first empirical study that examined the impact of financial development on carbon emissions by conceptualizing key notable variables such as institutional quality, FDI inflows, and renewable energy, which are significantly ignored in the prior works of Zhang (2011) and Jalil and Feridun (2011). Second, we formulate a comprehensive index of institutional quality to capture the effects of all important individual governance indicators extensively into one aggregate component by aggregating six key individual governance indicators into one aggregate institutional index. Next, we analyze the impact of each

[1] Xiong and Qi (2018) did not focus on the whole economy with a macroeconomic perspective.

institutional indicator on carbon emissions separately to diagnose more precisely the role of each governance indicator on environmental upgradation. In addition, we develop interactive proxy terms from prior research literature and thus add interactive term proxies (TRADE*FD) in our model. Also, our analysis is more robust as we utilize an updated dataset for the rapidly growing economy of China from 1996 to 2020 annually and also apply the most robust dynamic autoregressive distributed lag simulation methodology to control the endogeneity, multicollinearity, and autocorrelation issues for the time series dataset of our empirical research study.

The aim of the present study was to investigate, for the first time in the existing literature, the nexus among financial development, institutional quality, various other environmental factors, and $CO_2$ emissions for China over the period 1996–2020. In contrast to the previous studies that used conventional econometric approaches, this study fills the gap in the existing literature by employing up-to-date time series econometric approach dynamic ARDL simulations and provides reliable and robust results.

This study is organized as follows: **Section 2** presents the literature review. **Section 3** discusses data, model, and methodology, while results and discussions are reported in **Section 4**. The last section concludes the whole study with policy implications.

## 2 LITERATURE REVIEW

A vast body of existing literature identified a strong relationship between financial development and $CO_2$ emissions. For instance, Frankel and Romer (1999) argued that financial development attracts foreign direct investment (FDI) and hence leads to accelerated economic growth and $CO_2$ emissions. According to Tamazian et al. (2009), financial development increases environmental degradation. However, other researchers suggested that an established financial system not only helps improve the efficiency of the financial sector but also contributes to the economic development of a country (Sadorsky, 2010; Zhang, 2011; Shoaib et al., 2020). Ma and Fu (2020) and Dasgupta et al. (2001) argued that due to the development of the financial markets and expansion of production, the enterprises may reduce financing costs and increase financing channels to make investment in new projects, and this may stimulate energy consumption and carbon emissions. Khan et al. (2021) found that financial development, energy intensity, renewable energy production, research and development, natural resource depletion, and temperature contribute to environmental pollution degradation in Canada. Sadorsky (2010) identified that financial intermediation encourages people to take loans to buy heavy vehicles that ultimately accelerate $CO_2$ emissions. However, some researchers support that financial development can alleviate environmental degradation. For instance, Tamazian et al. (2009) emphasized that financial development helps companies reduce $CO_2$ emissions by adopting technological innovation, while Claessens and Feijen (2007) suggested that enterprises with advanced governance tend to be more willing to consider low-carbon development; therefore, financial development can promote corporate performance, and thereby reduce energy consumption and carbon emissions.

Recent literature has focused more on investigating the impact of financial development on environmental development in recent times (Boutabba, 2014). A study by Yuxiang and Chen (2011) investigated the impact of financial development on environmental pollution for the Chinese economy using provincial level data and concluded that financial development reduces the level of environmental pollution. The result estimations of their empirical study suggest that financial development improves environment conditions through the spread of technology, increase in capital, and enforcement of new environmental rules and regulations. Jalil and Feridun (2011) explored the effects of financial development, trade openness, and energy consumption on environmental degradation in the case of China from 1953 to 2006 annually by applying ARDL methods. The empirical results show a negative sign for the coefficient of financial development, suggesting that financial development did not contribute to environmental pollution in China. Quite the reverse, the results show that financial development reduced environmental pollution. Accordingly, energy consumption, trade openness, and income are the key determinants of carbon emissions ($CO_2$) in the long run. Moreover, the result estimates confirm the presence of an environmental Kuznets curve for China.

In addition, Zhang (2011) investigated the impact of financial development on carbon emissions in the long run. The empirical results showed that financial development is an important stimulator of carbon emissions that must be considered when carbon emission demand is highly anticipated. Second, the impact of financial intermediation on carbon emissions offsets that of other financial development indicators, but the impact of its efficiency seems to be weaker even though it might affect carbon emission statistically. Furthermore, although the Chinese stock market widely affects carbon emission, its efficiency influence is on a limited scale and quite weaker. Lastly, China's FDI has little impact on the size of carbon emission because of its smaller size relative to income. A study by Ozturk and Acaravci (2013) explored the nexus among financial development, energy consumption, economic growth, and carbon emissions for Turkey from 1960 to 2007 annually. The empirical estimations showed that there exists a relationship among financial development, income, carbon emissions, openness ratio, and energy consumption in the long run. Nevertheless, financial development had insignificant long-run effects on carbon emissions in the case of Turkey. Equally, developing countries can access new technology that might be environmentally friendly through the higher level of financial development in their country (Birdsall and Wheeler, 1993; Frankel and Rose, 2002). On the other hand, Jensen (1996) noted that financial development may lead to increased industrial activities, which, in turn, may lead to industrial pollution.

A study by Talukdar and Meisner (2001) explored the effects of financial sector development on carbon emissions for a panel

**TABLE 1** | Variable description.

| Abbreviation | Variable name | Measurement scale | Source |
|---|---|---|---|
| CO2 | Carbon dioxide | Metric tons | WDI https://data.worldbank.org/ |
| GOV | Governance | Institutional quality | WGI https://info.worldbank.org/g overnance/wgi/ |
| FD | Financial development | Domestic credit to the private sector (%GDP) | IMF https://data.imf.org/ |
| REC | Renewable energy consumption | % of total final energy consumption | WDI https://data.worldbank.org/ |
| FDI | Foreign direct investment | Net inflows (BoP, current US$) | WDI https://data.worldbank.org/ |
| TO | Trade openness | % of GDP | WDI https://data.worldbank.org/ |
| URB | Urbanization | % of total population | WDI https://data.worldbank.org |

of 44 developing countries from 1987 to 1995 annually. The empirical results showed that international capital flows and financial institutions positively influence environmental degradation. Claessens and Feijen (2007) studied the impact of governance on $CO_2$ emission, and they confirmed that firms can reduce carbon emissions with the help of technology-advanced governance. They concluded that financial development might enhance the productivity of the firms due to the promotion of innovative technology emits less energy, which ultimately decreases the rate of carbon emissions. Tamazian et al. (2009) explored the nexus among financial development, economic development, and environmental problems for BRIC economics from 1992 to 2004. The empirical results showed that a higher level of financial development improves environmental degradation. A study by Tamazian and Rao (2010) explored the impact of financial and institutional development on environmental pollution for 24 emerging countries from 1990 to 2004 annually and concluded that financial openness might be detrimental to environmental quality if it is not strongly interconnected with sound institutional quality.

Previous studies identified that urbanization (Balsalobre-Lorente et al., 2021; Qader et al., 2021), institutional quality (Usman and Jahanger, 2021), renewable/nonrenewable/total energy consumption (Usman et al., 2020; Hussain and Rehman, 2021; Usman and Makhdum, 2021; Regmi and Rehman, 2021; Rehman et al., 2021a; Rehman et al., 2021b), and trade (Rehman et al., 2021c; Rehman et al., 2021d; Usman et al., 2021) are more influencing factors that affect $CO_2$ emissions.

# 3 MODEL, DATA, AND ECONOMETRIC METHODOLOGY

## 3.1 Model and Data

This study investigates the role of institutional quality, financial development, FDI, trade openness, and renewable energy consumption in carbon emissions for China from 1996 to 2020. Inspired by Pata (2018) and Ehigiamusoe and Lean (2019), this study proposes the following model of **Eq. 1**:

$$\mathbf{CO_{2t}} = \boldsymbol{\beta_1} + \boldsymbol{\beta_2}\mathbf{GOV}_t + \boldsymbol{\beta_3}\mathbf{FD}_t + \boldsymbol{\beta_4}\mathbf{REC}_t + \boldsymbol{\beta_5}\mathbf{FDI}_t + \boldsymbol{\beta_6}\mathbf{TO}_t + \boldsymbol{\beta_7}\mathbf{URB}_t + \boldsymbol{\beta_8}\,(\mathbf{FD{*}TRADE})_t + \boldsymbol{\varepsilon}_t, \quad (1)$$

**TABLE 2** | Summary statistics.

| Variable | Obs | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|
| $CO_2$ | 25 | 5.217 | 1.978 | 2.513 | 7.405 |
| FD | 25 | 126.417 | 23.657 | 89.455 | 182.432 |
| GOV | 25 | 2.090 | 1.495 | –1.924 | 4.027 |
| TO | 25 | 44.845 | 10.144 | 32.424 | 64.478 |
| FDI | 25 | 3.236 | 1.097 | 1.310 | 4.725 |
| URB | 25 | 46.468 | 9.363 | 31.916 | 61.428 |
| REC | 25 | 18.478 | 7.527 | 11.338 | 30.537 |

where $CO_2$ emission is an environmental indicator; GOV is the governance index, FD is financial development, REC is renewable energy consumption, FDI is foreign direct investment, URB is urbanization, and TO is trade openness. The description of all indicators is reported in **Table 1**. We scrutinize the descriptive statistical results presented in **Table 1** showing the mean, maximum, minimum, and standard deviations of the variables. The results of descriptive statistics show the positive trends of all the variables. These variations seem sufficient for further empirical estimation.

## 3.2 Econometric Methodology

Jordan and Philips (2018) developed a new dynamic stimulated ARDL, namely, dynamic ARDL simulations, approach to overcome the complications in short- and long-run examinations of the autoregressive distributed lag (ARDL) approach, which was developed by Pesaran et al. (2001). The dynamic ARDL simulation approach estimates and predicts the probability change in the regress and one regressor while keeping the other regressors unchanged. On the other hand, the Pesaran et al. (2001) ARDL approach only examines the long-run and short-run linkages between variables. Although the implementation of the ARDL approach is very convenient, its dynamic form accepts the first difference and multiple lags of both the regressor and regress (Jordan and Philips, 2018). To estimate the dynamic ARDL simulations, all the variables in the econometric model must be stationary at the first difference I(I), and there should be cointegration among all indicators (Jordan and Philips, 2018; Sarkodie et al., 2019). This method uses the multivariate normal distribution to simulate the vector of parameters 5,000 times. The equational form of the dynamic ARDL simulation approach is presented in **Eq. 2.**

**TABLE 3 |** Unit root test results.

| Variable | ADF | | Phillips-perron | |
|---|---|---|---|---|
| | Level | First difference | Level | First difference |
| $CO_2$ | −0.884 | −3.135** | −0.727 | −2.664*** |
| Gov | −0.725 | −7.900* | −0.479 | −9.019* |
| FD | −0.827 | −4.481* | −1.494 | −4.346* |
| Trade | −1.878 | −3.636** | −0.367 | −3.628** |
| FDI | −1.980 | −4.275* | −2.153 | −4.170* |
| REC | −1.725 | −2.200** | −1.198 | −2.622*** |

*Note: *, **, *** denote 1, 5, 10%, respectively.*

$$\Delta y_t = \varnothing_0 Y_{t-1} + \varnothing_1 (X_1)_{t-1} + \cdots + \varnothing_k (X_k)_{t-1} + \sum_{k=1}^{m} \sigma_i \Delta(y)_{t-1} + \sum_{l=0}^{n_i} \partial_{ij} \Delta(x_1)_{t-j} + \cdots + \sum_{l=0}^{n_k} \partial_{kj} (x_k)_{t-j} + \mu_t \tag{2}$$

In **Eq. 2**, y demonstrates the variation in the dependent variable, $\varnothing_0$ is the intercept, t-1 is the maximum $p$-value of the regressor, $n_k$ shows the number of lags, $\Delta$ is the first difference, t is the time period, and $\mu$ is the error term. The null hypothesis of no cointegration $H_0 = \varnothing_0 + \varnothing_1 + \ldots + \varnothing_k = 0$ is checked against the alternate hypothesis $H_A = \varnothing_0 + \varnothing_1 + \ldots + \varnothing_k \neq 0$. The null hypothesis of no cointegration is rejected if the calculated value of F-statistics is greater than its critical value.

$$\begin{aligned}\Delta \ln(CO_2)_t = {} & \beta_0 \ln(CO_2)_{t-1} + \alpha_1 \Delta \ln(GOV)_t + \delta_1 \Delta \ln(GOV)_{t-1} + \alpha_2 \Delta \ln(FD)_t \\ & + \delta_2 \Delta \ln(FD)_{t-1} + \alpha_3 \Delta \ln(TO)_t + \delta_3 \Delta \ln(TO)_{t-1} + \alpha_4 \Delta \ln(FDI)_t + \\ & \delta_4 \Delta \ln(FDI)_{t-1} + \alpha_5 \Delta \ln(URB)_t + \delta_5 \Delta \ln(URB)_{t-1} + \alpha_6 \Delta \ln(REC)_t + \\ & \delta_6 \Delta \ln(REC)_{t-1} + \alpha_7 \Delta \ln(FD{*}TRADE)_t + \delta_7 \Delta \ln(FD{*}TRADE)_{t-1} + \varepsilon t\end{aligned} \tag{3}$$

# 4 RESULTS AND DISCUSSION

## 4.1 Unit Root Test

Before applying the dynamic ARDL simulation approach, the first step is to check the stationarity of all variables; that is, the dependent variable should be stationary at first difference I (1), while all independent variables must be stationary at level or at first difference, that is, I (0) or I (1). This study applies augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests to check the stationarity of all variables. The results of the unit root tests in **Table 3** demonstrate that all variables are stationary at first difference I (1).

## 4.2 Dynamic Autoregressive Distributed Lag Simulations

This study utilized dynamic ARDL simulations proposed by Jordan and Philips (2018), and this econometric approach overcomes the complexities in the existing ARDL approach. The results of the dynamic ARDL simulations are reported in **Table 4**. The proxies of the governance index, that is, RL and RQ, posit a negative relationship with $CO_2$ emissions. The positive sign of governance indicators denotes that an increase in rule of law and regulatory quality leads to an increase in $CO_2$ emissions in China. Our findings are consistent with Abid (2016).

The coefficient of trade has a negative and significant relationship with $CO_2$ emissions, which implies that trade helps mitigate environmental pollution. A potential reason is that China's higher economic growth rate and increasing income have reduced the trade barriers, which ultimately improves environmental quality. In addition, China has modified its manufacturing structure. Due to the higher demand for traded goods, China produces low-polluting goods which help reduce $CO_2$ emissions significantly. Our results are in line with Jayantha Kumaran et al. (2012), Shahbaz et al. (2013), Hao and Liu (2015), Yazdi and Beygi (2018), Chen et al. (2019), and Fatima et al. (2021a).

Financial development (FD) has a significant and negative impact on $CO_2$ emissions. The negative coefficient FD implies that financial developments cause R&D investments, thereby promoting the expansion of high-tech and environmentally friendly energy investment, in turn hindering carbon emissions. Furthermore, financial sector development contributes to reducing $CO_2$ emissions by guiding the banking sector to provide loans to companies for establishing environmentally friendly investment projects. Our findings are consistent with Shahbaz et al. (2013), Hafeez et al. (2019a), Hafeez et al. (2019b), Shoaib et al. (2020), and Szymczyk et al. (2021).

With respect to the coefficient of renewable energy consumption (REC), it is found that an increase in the share of renewable energy consumption adversely affects $CO_2$ emissions in China. In China, with increasing concerns about the health and environmental costs of $CO_2$ emissions, consumption of renewable energy must become an effective alternative to fossil fuels (such as oil, coal, and natural gas). Moreover, the increasing energy demand and huge consumption of nonrenewable energy sources exert an adverse impact on the environment. Our findings are in line with Bilgili et al. (2016), Danish et al. (2017), Ito (2017), Sarkodie and Adams, (2018), Bekun et al. (2019), Wang et al. (2020), and Anwar et al. (2021).

The coefficient value of foreign direct investment (FDI) demonstrates a positive and significant relationship with $CO_2$ emissions. FDI inflows increase the host country's $CO_2$ emissions by establishing more industrial units. In addition, foreign investors are attracted to invest in countries with lower environmental regulations in terms of $CO_2$ emissions; this factor ultimately leads to more $CO_2$ emissions. Our findings are similar to those of Paramati et al. (2016), Shahbaz et al. (2018), Chishti et al. (2021), Farooq (2021), and Mehmood (2021). Urbanization has a positive and significant relationship with $CO_2$ emissions, which reveals that urbanization is a highly significant factor of environmental degradation in China. On the one hand, urbanization promotes household energy consumption, which ultimately contributes to increase in $CO_2$ emissions; on the other hand, the process of urbanization in

**TABLE 4 |** Results for dynamic ARDL simulations.

| Variable | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|---|---|---|---|---|---|---|---|
| Lagged $CO_2$ | −6.67** (−2.43) | −0.79** (−2.46) | −0.95** (−2.88) | −0.71*** (−3.31) | −0.74** (−2.53) | −0.65*** (−3.30) | −0.65*** (−3.24) |
| GOV | −0.06 (−0.83) | | | | | | |
| ΔGOV | −0.07** (−2.03) | | | | | | |
| CC | | 0.47 (0.58) | | | | | |
| ***ΔCC*** | | 0.21 (0.48) | | | | | |
| RL | | | −1.09* (−1.78) | | | | |
| ***ΔRL*** | | | −0.60** (−1.91) | | | | |
| PS | | | | 0.05 (0.02) | | | |
| ***ΔPS*** | | | | 0.15 (0.62) | | | |
| RQ | | | | | −0.03*** (−0.05) | | |
| ***ΔRQ*** | | | | | −0.22 (−0.39) | | |
| VA | | | | | | −0.02 (−0.29) | |
| ***ΔVA*** | | | | | | −0.01 | |
| | | | | | | −0.36 | |
| GE | | | | | | | −0.22 |
| | | | | | | | −0.56 |
| ***ΔGE*** | | | | | | | −0.33** |
| | | | | | | | −1.49 |
| FD | −0.02 | −0.05 | −0.48 | −0.04** | −0.04* | −0.04** | −0.03 |
| | −1.24 | −1.72 | −1.73 | −2.11 | −1.88 | −2.63 | −1.66 |
| **ΔFD** | −0.05 | −0.05 | −0.05 | −0.06 | −0.06 | −0.05** | −0.05 |
| | −3.67 | −3.33 | −4.02 | −3.54 | −3.28 | −2.11 | −2.91 |
| TRADE | −0.08* | −0.14** | −0.14** | −0.13** | −0.13** | −0.02** | −0.11** |
| | −1.98 | −2.22 | −2.25 | −2.69 | −2.49 | −1.10 | −2.24 |
| **ΔTRADE** | −0.16 | −0.14 | −0.15 | −0.17 | −0.16 | 0.36** | −0.15 |
| | −3.37 | −2.87 | −3.73 | −3.20 | −3.09 | −2.11 | −2.72 |
| FDI | 0.26*** | 0.23** | 0.23*** | 0.24** | 0.21** | 0.25*** | 0.26** |
| | 3.02 | 2.31 | 2.95 | 2.53 | 2.19 | 3.70 | 2.69 |
| **ΔFDI** | 0.17 | 0.14 | 0.14 | 0.16 | 0.13 | 0.03** | 0.17 |
| | 2.87 | 2.19 | 2.27 | 2.52 | 2.00 | −2.18 | 2.36 |
| URB | 0.12* | 0.14** | 0.17** | 0.13** | 0.13* | 0.12*** | 0.12** |
| | 2.03 | 2.13 | 2.55 | 2.53 | 2.06 | 3.10 | 2.78 |
| **ΔURB** | −0.75 | −0.50 | −0.79 | −0.56 | −0.69 | −0.05** | −0.44 |
| | −2.06 | −1.34 | −2.06 | −1.61 | −1.02 | −1.19 | −1.37 |
| REC | −0.07** | −0.09* | −0.10*** | −0.66** | −0.07* | −0.06 | −0.05* |
| | −2.14 | −2.04 | −2.94 | −2.29 | −2.13 | −2.20 | −1.91 |
| **ΔREC** | −0.77 | −0.07 | −0.09 | −0.06 | −0.06 | −0.04** | −0.05 |
| | −2.08 | −1.77 | −2.66 | −1.55 | 3.24 | −2.12 | −1.33 |
| FD*TRADE | 0.07 | 0.01** | 0.01* | 0.01** | 0.001** | 0.01*** | 0.09* |
| | 1.10 | 2.15 | 2.04 | 2.55 | 2.34 | 3.41 | 2.07 |
| Δ(**FD*TRADE**) | 0.01** | 0.01** | 0.01** | 0.04** | 0.03** | 0.01** | 0.03* |
| | 3.14 | 3.07 | 3.72 | 3.27 | 3.24 | 3.29 | 2.72 |
| CONS | 2.61 | 5.69 | 4.98 | 4.34 | 5.20 | 3.69* | 2.72 |
| | 1.10 | 1.68 | 1.71 | 1.85 | 1.82 | 1.88 | 1.13 |
| Simulation # | 5,000 | | | | | | |
| Diagnostic tests | | | | | | | |
| Breusch–Godfrey LM | 0.10 | 0.77 | 0.12 | 0.08 | 0.10 | 0.09 | 0.11 |
| Breusch–Pagan (heteroscedasticity) | 0.24 | 0.63 | 0.40 | 0.51 | 0.28 | 0.17 | 0.24 |
| Skewness and kurtosis (normality) | 0.16 | 0.90 | 0.74 | 0.74 | 0.18 | 0.10 | 0.11 |
| | 0.20 | 0.36 | 0.18 | 0.18 | 0.28 | 0.14 | 0.42 |

*Note: ***, **, and * denote 1%, 5%, and 10% level of significance. Δ denotes the value of the coefficient of the explanatory variables in the short run.*

China is accompanied by an increase in consumption of goods and services such as housing and automobiles, leading to more indirect household $CO_2$ emissions. Moreover, the reason for rapid urbanization in China is that nowadays people prefer to live and work in urban areas, and they are moving rapidly to urban areas. Our estimated coefficient is parallel to that of Hossain (2011), Al-Mulali et al. (2013), Pata (2018), Mahmood et al. (2020), Gao and Zhang (2021), and Mignamissi and Djeufack (2021).

The coefficient value showed that the interaction term of financial development and trade is not environment friendly. This shows that a higher (lower) level of financial sector development in China will have higher (lower) export (import) share and trade balance in the financial sector. Over the past decades, many studies identified that financial development plays an important role in influencing a country's economic variables. For instance, King and Levine (1993a), King and Levine (1993b), and Levine (1997) found that a close relationship exists between the level of financial development and microeconomic and macroeconomic growth. Furthermore, the studies of Demirguc-Kunt and Maksimovic (1998), Beck and Levine (2001), and Rajan and Zingales (1998) demonstrated that a well-established financial sector helps countries obtain external financing for investment projects, while Svaleryd and Vlachos (2005) and Beck (2003) found a significant and positive correlation between financial development and international trade and comparative advantage.

The results of the diagnostic tests are presented in **Table 4**. The diagnostic tests are applied to check the consistency of econometric models. The results of the Breusch–Godfrey LM test demonstrate that no serial correlation was found in the model. The results of the Breusch–Pagan test show the absence of heteroscedasticity in the model. To check the normality of the dataset, we applied skewness and kurtosis tests. The results demonstrate that normal distribution existed under the null hypothesis.

## 5 CONCLUSION AND POLICY RECOMMENDATIONS

In recent years, climate change has become a serious issue that may lead to deterioration of sustainable development throughout the world. Over the past few decades, $CO_2$ emission has significantly and positively contributed to global warming, which has ultimately led to a change in climate across the globe. Thus, it is essential to examine those factors which significantly contribute to enhancing $CO_2$ emissions. This study investigates the impact of financial development, governance, foreign direct investment, urbanization, trade openness, and renewable energy consumption on $CO_2$ emissions in China over the period 1996–2020 annually.

The present study utilized an up-to-date time series econometric approach, namely, dynamic ARDL simulations proposed by Jordan and Philips (2018). The dynamic ARDL simulations overcome limitations in the already existing ARDL approach model. This approach used 5,000 simulations of the vector of parameters by utilizing multivariate normal distribution. The study examined the impact of financial development, institutional quality, and various other environmental factors, for example, renewable energy consumption, foreign direct investment, urbanization, and trade, on $CO_2$ emissions. The empirical findings of our study highlight that the proxies of governance index, that is, rule of law and regulatory quality; trade; financial development; and renewable energy consumption have a negative relationship with $CO_2$ emissions, while foreign direct investment and urbanization have a positive relationship with $CO_2$ emissions.

Based on the empirical findings, this study provides some important policy implications. First, since institutional quality adversely affects $CO_2$ emissions, policymakers must support local institutions to reduce environmental degradation. The lack of environmental protection policies in financial institutions has led to an increase in $CO_2$ emissions. Therefore, it is recommended to strengthen financial institutions and adopt environmentally friendly policies to decrease $CO_2$ emissions. The establishment of stable financial, economic, and environmental institutions contributes to green energy, thus helping mitigate environmental degradation. The findings of the study demonstrate that renewable energy consumption helps decrease $CO_2$ emissions in China, which in turn promotes sustainable development. In order to maintain environmental quality and establish an eco-friendly environment, policymakers must establish consistency between environmental and economic policies. In terms of limitation, as this study applies single-country analysis, further study can be extended by utilizing panel data for developed and developing countries.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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