Evaluating low-carbon economic peer effects of green finance and ICT for sustainable development: a Chinese perspective

Yujia Liu1 · Lianfeng Xia1

Received: 13 September 2022 / Accepted: 12 November 2022 / Published online: 25 November 2022
© The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2022

Abstract
With the adoption of the United Nations Sustainable Development Goals and the Paris Climate Agreement, ADB’s involvement should not be ignored. The Global Environment Facility (GEF) and ADB have teamed up to provide climate change financing for developing countries. Included in this is climate protection finance, the financing method that offers cash to assist the region in achieving ecological responsibility. Using a systematic framework, the researchers in this study examined the rationale for building a cohort result of green management in China in the new phase of the country’s development. As part of a multiplicative framework, the long-term correlation between variables is quantified using the dynamic common correlated effect (D-CCE) and interactive fixed effect. According to the findings, renewable energy and green financing are good environmental indicators. Environmental degradation is negatively affected by green governance. Some people are concerned about how to dispose of ICT, yet on the other side, ICT can help cut carbon emissions with new clean technologies. Moreover, the findings show that urbanization and per capita income increase carbon emissions. The results suggest that Chinese officials need to support reducing carbon emissions through the development of ICT infrastructure, green financing, and renewable energy.

Keywords Sustainable development · Green financing · Low carbon · D-CCE · China

Introduction
The connection between environmental preservation and economic development can be seen in the possible shift from pure waterways and green mountains to mountains of gold and silver (Lee and Lee 2022a; Zhang et al. 2023). This means that increasing the efficiency of green governance can assist in the purposeful choice to build an environmental civilization and the social dynamics between creation and preservation (Wu et al. 2021). General Secretary Xi Jinping stated that we must continue to improve social governance and resolutely implement green development to improve the ecological civilization system (Yin et al. 2021). When it comes to modernizing the governance ability and national governance system, a green governance system that has emerged is an essential part of this process. This includes integrating the spatial layout of production and ecological growth into the spatial arrangement of daily life (Tian et al. 2022). Local governments are under increasing pressure to reform due to environmental legacy and economic adjustment. Enhancing green governance is a serious route for local authorities to escape the growth challenge as a basic financial development strategy fades from the ancient phase (Ye et al. 2022).

Despite this, gaps in the expansion of social, economic, cultural, and political spheres can lead to ineffective government, which is why green governance cannot be implemented quickly (Jin et al. 2022). Green governance’s integration power is weakened since local governments are under pressure to change quickly (Huang et al. 2021; Muhammad et al. 2017). Using local government dynamics in the study of green governance helps to uncover the root causes of ineffective green governance, but it also has important conceptual significance for developing a new digitalization pattern that encourages the healthy coexistence of man and nature sustainably (Huang et al. 2022a, b; Khokhar et al.
This is the case in this context. In addition, it offers innovative ways for local authorities to handle their governing operations while achieving high-quality development and works to foster. A new era in China’s economy may be seen in local governments’ desire for green governance. As a key concept in the top-level design for local authorities at the beginning of the new stage, green governance enables environmentally friendly development that results in the building projects of a stable society. It makes it possible for supplies and the planet to work together orderly (Nawaz et al. 2021).

The financial industry and the environment are intertwined in protecting the environment. This is known as “green finance.” Environmental protection calls for financial innovation, and “green finance” refers to financial instruments developed for developing, promoting, and supporting productive activities with positive and long-term externalities (Yumei et al. 2021a). Environmental pollution and the effects of climate change are among the issues devoted to solving and promoting a more integrated economy (Yu et al. 2021a, b). Banking products and services incorporating environmental considerations into the loan decision, post-monitoring, and risk management are called green finance (Wen et al. 2022). Green finance promotes environmentally responsible investment and encourages the development of low-carbon technologies—three reasons why green financing is vital (Xiang et al. 2022). First and foremost, it encourages long-term progress. It is easier to establish and implement long-term business models, investments, trade, and economic, environmental, and social policies when financial instruments and related services freely flow around the globe. The second benefit is that it encourages banks to become more innovative and reduces the danger of breaking environmental regulations. Increasing the risk of a bank or lender if a borrower is fined for violating environmental rules will decrease the borrower’s profitability and capacity to repay the loan. After the financial crisis of 2008, businesses now place more emphasis on economic, environmental, and social cohesion rather than value creation for shareholders (Huang et al. 2022a, b).

Reducing carbon emissions through renewable energy has attracted considerable attention (Yu et al. 2021). Chinese renewable energy investments totaled $90.1 billion in 2019. Theoretically, renewable energy can help accelerate the transition to a low-carbon energy structure and reduce carbon emissions. Clean production and low-carbon technologies are two specific ways renewable energy can minimize carbon dioxide emissions. In light of concerns over China’s rising carbon emissions, questions still need to be answered. Is renewable energy’s impact on carbon emissions realistic? What’s the impact’s arc and amplitude? When it comes to promoting the use of renewable energy sources, how does the government make necessary policy adjustments?

Renewable energy’s impact on carbon emissions is a complicated issue (Dong et al. 2022). Renewable energy use, unlike non-renewable energy consumption, reflects the movement of capital. This suggests that reducing carbon emissions may directly result from the increasing use of eco-friendly products. Another reality is that Chinese renewable energy usage has a broad impact and is manifested in several forms and vast amounts. There have also been instances of wind and power farms that have been abandoned (Zhang et al. 2022).

There is a great deal of concentration on gaining governmental subsidies, which increases the uncertainty of how much time is turned into actual installations and power generation. Third, China’s lack of progress in renewable energy and carbon emission restrictions makes it impossible to perform large-scale statistical testing and build expertise in this area. Lastly, there are avenues for expanding research methods in order to deal with the difficulties inherent in the relationships’ complexity (Zheng et al. 2021).

Research into the elements that influence carbon emissions has covered a wide range of topics. It is always good to dig further into a subject. For starters, there are not any reliable statistics on how China’s use of renewable energy and green finance affects the country’s carbon emissions. Yet, there has been no consensus among scientists on how renewable energy and green finance consumption affect carbon emissions (Khan et al. 2021). This is not in line with China’s efforts to reduce carbon emissions by consuming renewable energy and green money. Another problem is earlier research focused almost exclusively on the linear relationship between carbon emissions and unimportant variables. When studying the impact of renewable energy and green financing on carbon emissions, it is vital to consider other core variables, such as green governance, information and communication technology, urbanization, and income per capita, because of the nature of renewable energy and green finance. A few studies have used a nonparametric additive model to investigate the factors influencing carbon emissions, although most studies have used a theoretical model (Liu et al. 2022a).

According to this report, using renewable energy and green financing might reduce China’s carbon emissions. To do this, we used the STIRPAT model to build a non-parametric additive regression model. Income per capita, urbanization, information, and communication technology (ICT), green finance, and renewable energy usage were all included when assessing their impact on carbon emissions. The empirical study relied on data collected for 10 years. Additional testing was carried out using the associated datasets, including unit root and co-integration testing and the Granger causality testing. There is a clear correlation between the amount of renewable energy consumed, the amount of carbon emissions emitted, and the direction and severity of this correlation. This research-driven support
benefits from climate change, carbon emissions reductions, renewable energy, and green finance policies. There are two significant contributions that this publication makes to the field. First, the study extensively assessed the influence of renewable energy consumption and green financing on China’s carbon emissions. The study also examined the impact of this influence in detail, providing a good reference for the role of renewable energy consumption in lowering carbon emissions and converting to low-carbon energy. A nonparametric additive model was used to examine the total influence of renewable energy on carbon emissions using a linear effects analysis and to analyze the variation in impact during different stages using a linear effect analysis.

Afterward, the rest of the paper is organized as follows. It is in the “Literature review” section that a review of previous studies is given. Data and methodology are covered under the “Data and methods” section of this report. Experiments are presented in the “Results and discussion” section. The “Conclusion and policy recommendations” section sums up the findings and discusses the policy implications.

**Literature review**

In order to meet the research objectives, this study aims to gather prior studies linked to renewable energy and carbon emissions, as well as green finance.

**Studies relevant to green finance and carbon emissions**

Recent studies have found that green financing can improve the environment by supporting environmental regulations and reducing carbon dioxide (CO2) emissions (Feng et al. 2022b, a). With its help, we can reduce our reliance on fossil fuels by 26%, which translates to a 12.4% drop in carbon dioxide emissions. Increasing private participation in green finance and investment can help achieve a variety of long-term development objectives (Zhang et al. 2021a). Despite its increasing prominence, few academics have studied the impact of green financing on environmental quality. As a result, the question arises as to whether the expanding trend in green financing increases the trade-off between environmental conservation and economic development. Little is known about the real connection between green money and environmental degradation despite its importance. For this work, the purpose is empirical evidence to fill this gap. In order to reap the benefits of environmental policies, stakeholders (organizations, governments, and regulators) may choose to participate in green finance. In order to encourage stakeholders to adopt green finance, it is important to understand its repercussions and the dynamics involved in improving environmental quality. An increasing number of stakeholders are becoming more conscious of the environmental impact of their actions (Zhou et al. 2022). A significant portion of this body of literature focuses on the environmental activities undertaken by end-users and those imposed on the company by some regulatory agencies or non-governmental organizations (Xiong and Sun 2022). The United Nations Framework Convention on Climate Change requires governments to consider environmentally friendly ways to reduce pollution. These programs appear to be dependent on green financing. As a result, a country’s leaders must offer green financing to transition to a green economy (Li et al. 2022). Regulatory agencies are more inclined to hunt for environmentally friendly financial resources now that new stakeholders and institutions are aware of environmental problems. In order to obtain environmental legitimacy, new ways of providing financial resources and green financing will need to be developed.

Countries worldwide have invested in green projects to protect the environment and improve environmental performance to assure green economic growth. Organizational skills and resources, such as green financing, are required to implement green knowledge (Zhang et al. 2021a, b, c, d). Energy restrictions are reduced, but so are CO2 emissions and economic growth, thanks to green finance (Zhang et al. 2021a, b, c, d). The adoption of green finance can be observed in a variety of methods. First, green financing aids businesses that pursue environmentally friendly innovations, such as purchasing green equipment, launching new environmentally friendly technology, and educating their personnel. Second, green financing through various projects helps stakeholders (organizations, governments, and regulators) to spend R&D on environmental challenges and minimizes the risk of green policies. It is also worth noting that green policies have a higher cost than standard methods. Green finance can help an organization avoid severe financial difficulties by allowing it to pay for these policies. Therefore, green finance may considerably reduce environmental pollution and enhance green policies by preserving natural resources and hazardous waste, and reducing CO2 emissions (S. Feng et al. 2022b, a).

According to Li et al. (2021), green finance is expected to lower the use of coal to 2.5% by 2030 and raise renewable electricity usage to 46% globally. Any investment that enhances the efficiency of the production process is referred to as green finance by Muganyi et al. (2021). Clean water, recycling, biodiversity, pollution control, environmental protection, and proactiveness are all examples of green finance that go beyond renewable energy and efficiency into the more extensive range of green activities (van Veelen 2021).
According to Pyka and Nocobi (2021), green investment can favor sustainable development goals. According to Taghizadeh-Hesary et al. (2022), private eco-friendly investment reduces CO2 emissions, transforming a growing economy into a green and low-carbon economy. Sustainable development and the Paris agreement can only be achieved through boosting green financing and environmentally friendly technology, according to a new study from (Chen et al. 2021). This study predicts that green financing will stimulate and facilitate environmental projects.

Studies relevant to renewable energy consumption and carbon emissions

REC, the environment (CO2 emissions), and economic growth are all linked in several empirical studies, which can be separated into three distinct research areas. The first one examines the relationship between economic growth and the utilization of renewable energy sources. According to Lv et al. (2021), renewable energy has a significant role in promoting economic growth in the United States. On the other hand, H. Liu et al. (2022a, b, c), on the other hand, studied the economic impact of renewable energy on 27 European nations between 1997 and 2007. A favorable correlation between renewable energy consumption and economic growth was found. However, this was largely due to a lack of exploitation of renewable energy resources in these nations, which supports the neutrality theory. The relationship between GDP, renewable energy certificates (RECs), and energy usage is examined by Arif et al. (2021). The VECM results show that GDP and REC are causally linked in both directions and that economic expansion is a long-term cause of both REC and EC. Similarly, their findings imply that Brazil’s economy is energy independent and that GDP is vital for providing the resources needed for sustainable development. Mngumi et al. (2022) analyze the relationship between REC and China’s economic development. While there is evidence of long-term two-way causation between Chinese growth and REC, there is no evidence of a long or short-term causality between CO2 emissions and REC. For example, Dong et al. (2021) focus on the relationship between economic growth and CO2 emissions in the Portuguese economy. The GMM model’s outcome indicates a favorable relationship between the three factors. The Granger causality test demonstrates a one-way correlation between RCE and economic growth. Using the VECM Granger causality analysis, Wang et al. (2021a, b, c) look at Pakistan’s REC and economic growth. Both variables appear to be linked in some way. According to their findings, Z. Liu et al. (2022a, b, c) investigated the connection between economic development, REC, energy, gross fixed capital formation, globalization, trade openness, and urbanization in Iran. Co-integration and long-term correlations between all variables were found in the results. There is evidence of a two-way causality between globalization, foreign direct investment (FDI), and real GDP.

Secondly, it examines the effect of renewable energy on environmental quality in the world around us. The studies examining the relationship between REC and CO2 emissions have been inconsistent. Per capita GDP growth has a positive and statistically significant impact on per capita REC, according to Guo et al. (2022), who present two empirical models for emerging nations. Over the long term, a 1% rise in GDP per capita results in a 3.5% increase in REC per capita. Mastini et al. (2021) indicate that NRE negatively influences GDP growth and increases CO2 emissions in European and Eurasian countries. Reducing greenhouse gas emissions has a favorable influence on GDP growth. REC legislation and policies implemented since 1978 have a beneficial and considerable impact on the REC, as shown by Streimikiene and Kaftan (2021), who looked into the connection between real GDP and CO2 emissions. CO2 emissions have had an overall positive effect on the Renewable Energy Credits (REC). Autoregressive (SVAR) analysis is used by Purnamawati (2022a, b) to analyze the relationship between REC and real GDP and CO2 emissions. According to their findings, a rise in renewable energy (RE) reduces CO2 emissions per capita.

REC, economic growth, and environmental quality are all examined in the third section of the paper Studies like Sharma and Choubey (2022) analyze the link between US CO2 emissions, nuclear and renewable energy use, and GDP. Nuclear energy appears to be a one-way link to CO2 emissions, but the Granger causality test shows no correlation between REC and CO2 emissions. Ning et al. (2021) examine the associate between CO2 emissions, REC, real GDP, and population density in the G7 countries and concludes that GDP, REC, and population density all contribute to CO2 emissions in these countries. The impact of income on emissions in emerging economies from 1990 to 2013 is examined experimentally by Akomea-Frimpong et al. (2021). According to the findings, income and CO2 emissions are correlated. Even if the EKC hypothesis is correct and wealth and environmental degradation are directly linked, not all models support it. An investigation on the link between emissions and economic growth was conducted by Hou et al. (2022) in a sample of 16 Asian countries. In the long run, their findings imply that REC, GDP, and emissions are all linked causally. Oil prices, renewable energy certificates (REC), carbon dioxide emissions, and GDP are all examined by Saeed Meo and Karim (2021) in OECD countries. The empirical evidence confirms a long-term quadratic link between emissions and economic growth, which supports the EKC theory. In the medium and long term, emissions and REC have a bidirectional relationship, as shown by Granger’s causality studies. According to current research,
REC has a crucial role in the sustainable development level in the nations studied. As a result, REC relies heavily on developing human capital and reducing CO2 emissions.

Data and methods

Data collection

Data availability and the actuality of green governance are considered while selecting a sample observation period for this paper’s research, which includes 31 provinces in China, from 2010 to 2019. Because provincial governments wield greater administrative power and are key players in green governance policies at the grassroots level and in shaping the climate for green development, local data was chosen for this analysis. According to S. Zhang et al. (2021a, b, c, d), it is challenging to accomplish prefectural-level green governance because it requires a strong theoretical, historical, and practical logic that unites all aspects of society, including people’s livelihoods and civil rights. Other environmental considerations, such as per-capita income and the amount of renewable energy used, are also being considered. Table 1 lists the measurements and sources for each unit in detail.

Theoretical background

York et al. (2003) have long considered IPAT a straightforward and helpful theoretical framework for studying the human drivers of environmental change. The IPAT model considers the effects on the environment of population growth, economic prosperity, and technological progress (York et al. 2003). Using the IPAT model, we can say that:

\[ I = P \times A \times T \] (1)

On the other hand, the impact and IPAT models have very limited applicability because they do not allow for non-monotonic and non-proportional changes in the influencing elements. Dietz and Rosa [reference] reworked the IPAT identity into a stochastic form to produce the STIRPAT model in order to address this concern. This stochastic model has been widely used for studying environmental change. The following notation denotes the STIRPAT model:

\[ I_i = \alpha P_i^a A_i^c T_i^d e_i \] (2)

an error term \( e \) can be written as follows: where an error term \( e \) is written as follows: where an error term \( b \) is written as follows: It will convert to IPAT identity when all values of \( a, b, c, d, \) and \( E \) are equal to 1. It is feasible to convert Eq. (3) into:

\[ \ln I_i = \ln \alpha + \ln P_i + \ln A_i + \ln T_i + \ln e_i \] (3)

IPAT/STIRPAT is a coordinated research initiative to figure out how human systems interact dynamically with the ecosystems on which they depend. The STIRPAT model is flexible enough to incorporate new influencing factors specific to a given study by including the ability to decompose each element into its parts. The STIRPAT model, on the other hand, analyses environmental change from a scientific perspective and a policy one. IPAT/STIRPAT has been the most extensively used theoretical model for assessing the impact of CO2 emissions on the climate. With reference to earlier studies, the STIRPAT theoretical model is also extended to fit our design needs in this study.

Initially, the first extension was developed because CO2 emissions are affected by the efficiency of fossil fuels. There are a number of ways to measure fossil energy efficiency, such as the ratio of usable output to input. Second, this study examines the %age of renewable energy consumption (RES) in the energy mix, which can reduce CO2 emissions by reducing the direct use of fossil energy. Third, urbanization is included in the model, indicating rational consumers’ carbon content. Exogenous variations in CO2 emissions are also explained by green governance, green financing, and information and communication technologies.

Taking all of this into account, the study proposes the following dynamic panel data model:

\[ LCO_{2,i,t} = \beta_0 + \beta_1 \ln URB_{i,t} + \beta_2 \ln GDPC_{i,t} + \beta_3 \ln ICT_{i,t} + \beta_4 \ln RE_{i,t} + \beta_5 \ln GF_{i,t} + \mu_{i,t} \] (4)

Table 1 Description of variables

| Variable | Unit                           | Source                              |
|----------|--------------------------------|-------------------------------------|
| GDPC     | GDP per capita                 | China Statistical Yearbook          |
| GF       | climate mitigation finance (CMF) in billions of US dollars | China Statistical Yearbook          |
| GG       | Green governance efficiency in the previous year | EPS data platform                  |
| RE       | Renewable energy consumption % of total energy | China Statistical Yearbook          |
| URB      | % of the total population      | China Statistical Yearbook          |
| ICT      | Internet users (per 100 people) | China Statistical Yearbook          |
| CO2      | Carbon emissions (Kt)         | China Statistical Yearbook          |
This indicates the total annual CO2 emissions from a set of provinces in a certain nation in the year \( t \), where \( t \) is the year, and \( I \) is the country urbanization (URB) is the abbreviation for the term. GDPPC is for gross domestic product per capita, and ICT stands for Internet Users as a whole. Renewable energy consumption (RE), green governance (GG), and green finance (GF) are the acronyms for these concepts. \( \beta_1–\beta_6 \) are the estimated parameters, while \( \varepsilon_1 \) is a random disturbance term in Fig. 1.

### Estimation strategy

As a panelist, it is important to keep in mind the importance of cross-sectional dependency (CD) (Dong, Sun, et al., 2018). Consequently, three tests, the CD test by Pesaran et al. (2004), the CD test by Friedman (1937), and the CD test by Frees (1995) are used to decide on an appropriate panel approach. However, the CD ratio test can be expressed mathematically as follows:

\[
CD = \sqrt{\frac{2T}{N(N-1)}} \left( \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \rho_{ij} \right) N(0, 1) \tag{5}
\]

\[
FRI = (T-1) \left[ \frac{2}{N} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \gamma_{ij} + 1 \right] \chi^2(T-1) \tag{6}
\]

\[
FRE = \frac{C(\theta)}{SE(Q)} \tag{7}
\]

In OLS, regression is the coefficient of residuals association. \( SE(Q) \) is the \( Q \) distribution’s standard error, and \( ij \) is the rank coefficient of Spearman’s matrix. When using panel CD, Fisher’s first-generation unit root test can be expressed in the following manner:

\[
\Delta y_{it} = \alpha_i + \gamma_i y_{i,t-1} + \sum_{j=1}^{k} \lambda_i y_{i,t-1} + \varepsilon_{i,t} \tag{8}
\]

And the random disturbance term is represented by \( \Delta y_{i,t} \), which stands for the first difference between \( y_i \) and \( T \) at the \( it \) observation of the panel, just like \( \gamma_i \), \( \varepsilon_i \), and \( T \). It is possible to state, assuming we are using the CD (Pesaran 2006) CADF as our second-generation unit root test:

\[
\Delta y_{it} = \alpha_i + \lambda_i y_{i,t-1} + \sum_{j=1}^{r} \Delta y_{i,t-1,j} + \varepsilon_{i,t} + \varepsilon_{i,t} \tag{9}
\]

The CADF model’s parameter \( t \) statistics can be used to measure CIPS.

\[
\text{CIPS} = \sum_{i=1}^{N} \frac{t}{N} \tag{10}
\]

Co-integration testing is the next step. There is a long-term correlation between the concern variables when both series are integrated in the same order. Co-integration can be used to spot long-term equilibrium processes. We used the Durbin Hausman group male’s co-integration test, developed by Westerlund and Edgerton (2008). The CD ratio can be used in this test, and prior knowledge of the integration sequence of variables is not required. Consequently, it can be used in the following situations.

### Interactive fixed effect

Regression models with factor error structures have been studied in two ways. The D-CCE approach, developed by Chudik and Pesaran (2013) as an extension of Pesaran (2006), is a popular tool for determining the common component in error structures. A new CCE method for linear static panel models with homogenous and heterogenous coefficients was developed by Pesaran (2006). A proxy for common factors, which can be extremely important in econometric contexts, is calculated using the cross-sectional average of the explained and explanatory variables instead of the factor component. For a variety of reasons, this research relied on the D-CCE approach given by Chudik and Pesaran (2013). (1) Using the cross-sectional and lagged cross-sectional mean values of the explained variables resolves the CSD problem in the data; (2) this methodology is robust against omitted variable bias and bidirectional feedback for various proxies of the environment and its determinants; and (3) this technique allows for ED heterogeneity (Hai Ming et al. 2022). In addition, Nasir et al. (2022) recommended the IFE as a second method to consider. An iterative mechanism combines the factor element and the regression coefficient. Following Eq. (11), it is determined that this methodology is ideal for our investigation.

\[
Y_{i,t} = X_{i,t} \beta + \varphi_i + s_i + \varepsilon_{i,t} \tag{11}
\]

where \( Y_{i,t} \) is the ED indicator in an economy \( i \) for period \( t \).

\[
\varepsilon_{i,t} = \Gamma_{i} \Gamma_{t} + \mu_{i,t} \tag{12}
\]

As seen in Eq. (12), the unit specification reaction to the standard shocks \( \Gamma_{i} \) \( I \) is a \( r \) multiplied by 1 vector of the factor loading, and \( F_{t} \) is a \( r \) multiplied by 1 vector of unobserved time-specific common shocks. For both factoring and regression coefficients, Bai (2009) advocated minimizing the sum of residual square (SSR) (Eq. (13)).

\[
SSR = \sum_{i=1}^{N} \sum_{t=1}^{T} \left( Y_{i,t} - X_{i,t} \beta + \varphi_i + s_i - \Gamma_{t} \mu_{i,t} \right)^2 \tag{13}
\]

There are two ways to calculate the regression coefficient and the factor structure of \( \Gamma_{i} \) \( F_{t} \): First, if the factor structure has been discovered and SSR is minimized, then the regression coefficient can be determined.
Then, $Y_{i,t}^{(1)} = Y_{i,t} - iF_{t}$. It is also possible to use analysis of principal components if the regression coefficients are recognized, in which case we can use the commonly used normalization of $T^{-1} \sum (t=1)T_{t}F_{t}^{t} = I_{r}$:

$$SSR_{2} = \sum_{i=1}^{N} \sum_{t=1}^{T} \left( Y_{i,t}^{(2)} - \Gamma_{t}^{(2)}F_{t} \right)^{2} = Y_{i,t}^{(2)} - X_{i,t}^{(2)}\beta - \phi_{t} - s_{t}$$

(14)
SSR1 and SSR2 given in Eqs. (14) and (15) should be iterated upon until the difference in SSR is less than pre-specified assessment documents, according to Nasir et al. (2022).

**D-H panel causality test**

The D-H panel causality test, an advanced version of panel causality developed by Dumitrescu and Hurlin (2012), determines whether or not there is a link between the different variables under investigation. Causality is tested using heterogeneous panel data methods. This methodology has three advantages: it considers the CSD ratio, the time dimension, and cross-section size in relation to each other. It provides appropriate results even when the data are unbalanced.

**Results and discussion**

Data from the variables are shown in Table 2 as descriptive statistics. Defining the variable’s characteristics is essential in conducting further empirical research. Climate change, urbanization, per capita income, renewable energy use, information and communication technology, green financing, and green governance are the main topics of this investigation. Table 2 shows that the mean and median values of the selected variable do not differ significantly.

The unit root and co-integration tests that best fit our data are used to begin the study. Various CD ratio assays are used in this investigation, as described above. Results of CD testing for selected provinces are shown in Table 3. All of these tests statistically reject H0 at the 1% level of significance, and hence each series contains CD.

For a more in-depth look at the results, see Table 4. According to the results of the CADF tests, carbon emissions and green governance in the economies tested are stationary at the level, whereas URB, GDPC, ICT, RE, and green finance are all stationary at the first difference.

Using the second-generation panel unit root test as a starting point, this investigation ran a second-generation panel co-integration test to confirm the results (Westerlund and Edgerton 2007). Since it can detect mistake repair and offer proof of co-integration, the second-generation technique has two distinct advantages. A lack of co-integration between variables, as shown in Table 5, is rejected as a null hypothesis. Due to co-integration, long-term estimators D-CCE and IFE models must be used.

**Long run result of D-CCE and IFE estimators**

For this study, the long-term correlation between variables is investigated using the dynamic common correlated effect (D-CCE) mean group and the interactive fixed effect (IFE) estimators. Researchers in China looked at 31 provinces’ carbon emissions as a function of factors such as population density and per capita income as well as energy efficiency, renewable energy, green finance, and environmentally friendly government. There appears to be a positive correlation between urbanization and carbon emissions based on the URB coefficient [1.692 (D-CCE) and 1.045 (IFE)]. So, 1% in this factor would increase emissions by 1.692% and 1.045%. The following is a concise summary of the theoretical underpinnings for the link...
between China’s urbanization and carbon dioxide emissions. Manufacturing activity and industrial development are concentrated in emerging cities during the early stages of urbanization. First and foremost, the agricultural sector’s labor force is shrinking as a result of urbanization, while the two-sector economy continues to grow. Industry at this period used a lot of fossil fuels, like coal and gasoline, because of the primary technology. Low-energy intensity agriculture produces a substantial amount of CO2 emissions. As a result of urbanization, the requirements and behaviors of private homes are also changing. There is a greater dependence on commercial goods and services for urban families (Yu et al. 2021). Energy consumption, such as heating systems and electric appliances, generates a significant amount of GHG. Third, the need for intercity and confined city transportation is increasing due to urbanization (Ning et al. 2022). As private and public transport use increases, so does the environmental impact. Another consideration is the increased demand for infrastructure and cities’ growth and associated industries. Infrastructure projects that use a lot of energy and lead to higher emissions, such as highways, bridges, sewage systems, and the like, are common (Wang et al. 2021a, b, c). In addition, the land becomes increasingly scarcer as cities grow in population. Erecting multi-story structures, which require a lot of electricity, is on the rise. There will be an increase in the size of cities. However, agriculture and natural places might be easily taken over. The combination of these mechanisms increases carbon dioxide emissions.

The GDP per capita (GDPC) of China’s provinces is also a factor in calculating the country’s carbon emissions. CO2 emissions are directly linked to this element. This means that a 1% rise in this component would lead to a 0.654% and 0.872% increase in carbon emissions, respectively. From the combustion of fossil fuels and the production of cement, China is responsible for 75% of the rise in global carbon emissions between 2010 and 2012 (Wang et al. 2021a, b, c). Furthermore, China’s carbon emissions from burning fossil fuels and manufacturing cement were overestimated (Lee and Lee 2022a, b). China’s largest contributions to CO2 emissions from fossil fuel combustion were 0.16 0.02 watts per square meter (Debrah et al. 2022), suggesting that China is a major driver of global carbon emissions. Decoupling performance in China-led Asia is always worse than in

Table 5 Westerlund cointegration test

| Statistics | Value | Z-value | P-value | Robust P-value |
|------------|-------|---------|---------|----------------|
| \( G_t \)  | -11.335 | 7.354   | 1.000   | 0.000          |
| \( G_s \)  | 3.465  | 5.578   | 1.000   | 0.658          |
| \( P_t \)  | -1.389 | 3.245   | 1.000   | 0.196          |
| \( P_s \)  | -6.852 | 4.598   | 1.000   | 0.001          |

Europe and North America because of significant increases in carbon emissions. China’s economy has grown at a double-digit rate since entering the World Trade Organization in 2001 is widely known, and increased carbon emissions have accompanied this growth. Another principle in Copenhagen was “shared but differentiated responsibility,” according to the Accord (developed countries implement compulsory carbon emission reduction while developing countries take voluntary actions). While environmental considerations in wealthier regions have been diminished by this notion of “shared but differentiated duties,” in less developed places, they have been strengthened. Europe and North America did demonstrate a good decoupling between 2000 and 2017. However, the entire global performance was still in a weak decoupling state because of Asia’s constraints during that period (Saeed Meo and Karim 2021).

According to the coefficient value, information and communication technology (ICT) negatively influences carbon emissions. A 1% increase in this factor would result in reductions of 0.428% and 0.595% in carbon emissions, respectively. Intriguing discoveries can be gleaned from the preliminaries. Both internet users and their carbon emissions are negative and substantial at the 1% level when focusing on ICT variables. Increased Internet usage appears to minimize carbon emissions, according to the findings. Furthermore, the influence of ICT variables on carbon emissions persists regardless of the method used to assess them. Carbon emissions in the manufacturing, residential, and transportation sectors are routinely and significantly reduced by Internet usage. According to the findings, ICT has an important role in lowering carbon emissions (Purnamawati 2022a, b). This may be because China’s provinces, following the execution of the Masterplan, have pushed a broader embrace of ICT sector development. Developing an ICT infrastructure that can enable innovative, cleaner, and more efficient technologies is the goal of this project. In contrast, subsequent studies have found ICT inconsequential or harmful to the environment (Nabeeh et al. 2021).

Carbon emissions are also reduced through the use of renewable energy. Carbon emissions would be reduced by 0.085% and 0.153%, respectively, if a 1% increase increased this factor. In the case of 85 developed and developing economies studied from 1991 to 2012, Iqbal et al. (2021a, b) found that the use of renewable energy contributed positively to economic growth and mitigated environmental degradation; however, Zeng et al. (2022) found the opposite in the case of 19 developed and developing economies studied from 1991 to 2012. Using renewable energy as a substitute for fossil fuels could be boosted if production efficiency for renewable energy sources improves. Increasing renewable energy can reduce our dependence on non-renewable resources and help us overcome environmental issues. In addition, numerous
renewable energy sources are an important part of the energy production process. The growth of this resource removes toxic gases that contribute to climate change. Consequently, these benefits are insufficient to counteract the negative environmental impact of renewable energy use in the selected panels. The environmental impact of several polluting biomass wastes could be reduced using progressive renewable conversion technology.

The relevance of green finance in reducing carbon emissions cannot be overstated. Carbon emissions would drop by 0.195 and 0.236%age points, respectively, with a 1%age point increase in this component. Green finance significantly influences provinces with higher economic growth, foreign investment, and financial assistance than those with lower levels. In cross-country studies, a country’s absorptive capacity, as reflected by economic and financial conditions, can enhance the positive impact on growth (Moşteanu 2020; Saha et al. 2022), and these results are consistent with this hypothesis (Srivastava et al. 2021). In order to get the most out of green financing, China’s local governments must be fully cognizant of the significance of their economic activities.

Lastly, carbon emissions are determined by green governance and demonstrate an inverse relationship with the previously explained variables. If this component rises by one %, carbon emissions could fall between 0.005 and 0.008%. The results reveal that the factor is usually important and positive, indicating local authorities’ strong peer influence on green governance. According to the comparison, when local governments in an area collaborate on green governance initiatives, they have a greater chance of influencing each other’s actions. The peer effect is also present within regions. As a result, green governance homogenous groups within the same region with equal levels of progress are affected by rivalry within the scale. This leads to a small reduction in peer activism in spatial relationships as every player fears their loss of influence. However, the environmental channels are weaker due to green governance, suggesting that higher green governance is likely to reduce environmental damage (Table 6).

### D-H panel causality test

Table 7 shows that all regressors Granger causally explained variables in the DH panel. As a result, our findings suggest that environmental regulations can impact emissions levels by focusing on the variables studied. In the long run, these causal orientations are consistent with our predictions. Carbon emissions are directly linked to urbanization, implying that any considerable increase in urbanization would have a negative impact on the environment, and there is feedback from urbanization to carbon emissions. There is a two-way causal link between per capita income and carbon emissions, indicating that policies affecting per capita income and emissions are linked and function in concert. Both the level of carbon emissions and the use of ICT have direct causal relationships with information and communication technology. Emissions and green governance are also linked by the feedback theory, which claims any significant change in ICT level would lead to an increase in carbon emissions and vice versa. Finally, there is a one-way relationship between carbon emissions and green money. If the level of carbon emissions were to alter significantly, we would have to insist on investing in green financing in order to minimize them.

### Table 7 Results of D-H panel causality

| Null hypothesis | W-stat | P-value |
|-----------------|--------|---------|
| LURB > LCO₂     | 10.2334| 0.000   |
| LCO₂ > LURB     | 8.1423 | 0.005   |
| LGDPC > LCO₂    | 7.5513 | 0.000   |
| LCO₂ > LGDPC    | 3.9874 | 0.000   |
| LICT > LCO₂     | 7.6189 | 0.000   |
| LCO₂ > LICT     | 5.6532 | 0.003   |
| LGF > LRE       | 2.4578 | 0.332   |
| LCO₂ > LRE      | 0.2245 | 0.994   |
| LGG > LCO₂      | 3.4198 | 0.089   |
| LCO₂ > LGF      | 6.2454 | 0.000   |
| LGG > LCO₂      | 5.6958 | 0.003   |
| LCO₂ > LGG      | 4.8710 | 0.000   |

### Table 6 Long-run outcomes of D-CCE and IFE estimators

| Variable | D-CCE estimator | IFE estimator |
|----------|----------------|--------------|
|          | Coefficient    | Std. error   | P-value | Coefficient    | Std. error | P-value |
| LURB     | 1.6923         | 0.5412       | 0.001   | 1.0456         | 0.2598     | 0.000   |
| LGDPC    | 0.6542         | 0.1102       | 0.000   | 0.8724         | 0.3241     | 0.000   |
| LICT     | -0.4287        | 0.1023       | 0.005   | -0.5952        | 0.1932     | 0.002   |
| LREI     | -0.0852        | 0.0024       | 0.008   | -0.1532        | 0.0965     | 0.000   |
| LGF      | -0.1955        | 0.0985       | 0.001   | -0.2365        | 0.1198     | 0.000   |
| LGG      | -0.0056        | 0.0012       | 0.006   | -0.0089        | 0.0013     | 0.000   |
| Cons     | -3.8965        | 0.8954       | 0.000   | 1.4512         | 0.1288     | 0.000   |
Conclusion and policy recommendations

There are 31 provinces in Canada, and this study focuses on determining the elements contributing to carbon emissions in those provinces from 2010 to 2019. According to the findings, there is a link between rising urbanization, rising per capita income, and rising carbon emissions. ICT and renewable energy use are gradually reducing environmental deterioration. On the other hand, green governance and green finance minimize pollution levels. This study uses the D-H panel causality test to examine the relationship between the variables. As predicted, renewable energy use and CO2 emissions have a bidirectional Granger connection. There should be additional information on the historical values of the renewable if Granger causality exists between CO2 emissions and renewable (and vice versa) if this is the case. Emissions from using renewable energy could be compared to the same situation. On the other hand, urbanization and carbon emissions were causally linked in both directions, as were income per capita and emissions of CO2, as were the use of new technologies and emissions of CO2. According to a neutral hypothesis, ICT and carbon emissions are not linked.

Some policy recommendations are made to support the outcomes, such as accelerating the progress of some determinants and reducing environmental harm. The practical extension of fiscal support for green governance will be enhanced through fiscal restructuring and asset revitalization. Local governments’ inability to properly manage their finances is reflected in the ripple consequences of green governance. When it comes to green governance, local governments are heavily reliant on fiscal output, and they aim to take advantage of this dependency in order to boost their financial clout and “fight” for authority with the federal government. The institutional system of local governments has become perplexed as a result of the conflict between green governance’s incentive logic and the environmental basis of financing. Confusion about governance has resulted in irrational behavior, like regions that mindlessly follow the current trend, neglecting their mature and robust budgetary underpinnings, and distorting the route of green governance, which will only finally lead to a systemic catastrophe of ineffective government and hunger. Local governments should be encouraged to invest in green governance and guided to understand the financial operations of wealthy areas to promote green governance in a small-scale and high-energy asset operation state. Finally, to prevent local governments from incurring significant debt risks in their financial turnover, implement a zoning strategy and precisely match the budget deficit for green governance.

According to the linear effect study, increasing China’s total renewable energy subsidies for emissions reductions has been restricted. A carbon emission influence coefficient of 0.085 was found for renewable energy, showing that it had a much less impact on carbon emissions than per capita GDP or any of the other variables. This indicates that renewable energy has not played a dominant character in lowering carbon discharges. China’s energy consumption structure has not changed much, and the efficiency of renewable energy consumption has been low. Thus, this may be the reason why. It is difficult to predict how much of a difference renewable energy source will have on global releases. When renewable energy was in its early phases, carbon emissions had not been appropriately reduced by renewable energy. When it comes to reducing greenhouse gas emissions, renewable energy is beginning to play an important role in this phase. Renewable energy may raise carbon emissions in the final stages. Rising demand for fossil fuels and subpar returns on renewable energy investments could be to blame.

China’s rapid economic development is critical to the country’s efforts to reduce CO2 emissions, which should be prioritized for future sustainable development during the period of economic and social development and transition in China. This paper’s RDP analysis shows that to keep major pollutants under control, the government must continue to invest in upgrading and transforming low-efficiency industries with excess production capacity and bolstering regulatory and financial support for emerging high-tech industries like telecommunications, the web, and artificial intelligence. Now is the time to increase support and investment in R&D operations in China’s northwest and southwest, which will be critical in the future to reducing carbon emissions and ensuring sustainable development.

Continue to execute cooperative policies on sustainable consumption and production, such as expanding the ICT industry and renewable energy, to help China achieve its goals. Because agriculture and industry are the region’s two most important economic drivers, its rapid economic development has spawned a slew of environmental issues. Increasing the demand for fossil fuels, which can lead to additional carbon emissions, is a result of these actions. Despite China’s support for climate change issues under the United Nations Framework Convention on Climate Change, the recent coronavirus pandemic has proved that increasing online activities can drastically reduce carbon emissions, as shown by the Kyoto Protocol. Developing a robust ICT sector with high levels of renewable energy may help reduce carbon emissions, but cutting all economic activities is not an option.

Policymakers in China’s provinces with greater city development must focus on accelerating urbanization and developing public infrastructure to benefit from agglomeration and scale economies. At this point, the economy and society are undergoing significant structural change, often accompanied by an increase in industrialization. There should also be a guide to sustainable living, such as green
travel and renewable energy use, put together by our governments. To avoid traffic jams and overpopulation, countries with a high level of urbanization should focus on efficient and well-organized urban expansion. Even though the country’s urbanization level has reached a turning point, the total carbon footprint may continue to rise if the urban population remains inefficiently concentrated in a few metropolises.

While this work fills a gap in the existing research on how green finance and renewable energy use affect the environmental level, several problems remain unsolved and should be specified, suggesting potential directions for future research. Finally, our initial study quantifies how green finance affects renewable energy use and carbon emissions in a linear framework. As a result, much attention has been paid to nonlinearity in the interaction between economics and the environment in the last few years, especially concerning political concerns. A full picture of green productivity development could be gained by examining how green financing and renewable energy affect carbon emissions in different countries. First and foremost, sustainable development is an umbrella phrase that encompasses various economic, environmental, and social circles. This study focuses mostly on economic and environmental outcomes due to the difficulties of evaluating social benefits. In the future, more studies on green productivity growth could consider this factor.

**Author contribution** Yujia Liu: conceptualization, data curation, methodology, writing—original draft, data curation, Lianfeng Xia: visualization, supervision, editing, writing—review & editing, and software.

**Data availability** The data can be available on request.

**Declarations**

**Ethical approval and consent to participate** The authors declare no competing interests.

**Consent for publication** N/A.

**Competing interests** The authors declare no competing interests.

**References**

Akomea-Frimpong I, Adeabah D, Ofosu D, Tenakawah EJ (2021) A review of studies on green finance of banks, research gaps and future directions. J Sustain Financ Invest. https://doi.org/10.1080/20430795.2020.1870202

Arif M, Hasan M, Alawi SM, Naeem MA (2021) COVID-19 and time-frequency connectedness between green and conventional financial markets. Glob Financ J 49:100650. https://doi.org/10.1016/j.gfi.2021.100650

Chen Q, Ning B, Pan Y, Xiao J (2021) Green finance and outward foreign direct investment: evidence from a quasi-natural experiment of green insurance in China. Asia Pacific J. Manag. 1–26https://doi.org/10.1007/s10490-020-09750-w

Chudik A, Pesaran MH (2013) Econometric analysis of high dimensional VARs featuring a dominant unit. J Econom 69:393–414. https://doi.org/10.1016/j.jeconom.2012.02.014

Debrah C, Chan APC, Darko A (2022) Green finance gap in green buildings: a scoping review and future research needs. Build Environ 207:108443. https://doi.org/10.1016/j.buildenv.2021.108443

Dong F, Zhu J, Li Y, Chen Y, Gao Y, Hu M, Qin C, Sun J (2022) How green technology innovation affects carbon emission efficiency: evidence from developed countries proposing carbon neutrality targets. Environ Sci Pollut Res 29:35780–35799. https://doi.org/10.1007/s11356-022-18581-9

Dong S, Xu L, McIver R (2021) China’s financial sector sustainability and “green finance” disclosures. Sustain. Accounting. Manag Pol 12:353–384. https://doi.org/10.1108/SAMP-10-2018-0273

Dumitrescu EI, Hurlin C (2012) Testing for Granger non-causality in multiple VARs featuring a dominant unit. Econom Rev 32:675–701. https://doi.org/10.1080/01601071.2011.6108/740374

Feng S, Zhang R, Li G (2022b) Environmental decentralization, digital finance affects renewable energy use and carbon emissions from agricultural production. Agric. 2022. Vol. 12, Page 313 12, 313. https://doi.org/10.3390/AGRICULTURE1203013

Hai Ming L, Gang L, Hua H, Waqas M (2022) Modeling the influencing factors of electronic word-of-mouth about CSR on social networking sites. Environ. Sci. Pollut. Res. 1–18 https://doi.org/10.1007/s11356-022-20476-8

Hou D, Chan KC, Dong M, Yao Q (2022) The impact of economic policy uncertainty on a firm’s green behavior: Evidence from China. Res Int Bus Financ 59:101544. https://doi.org/10.1016/j.ribaf.2021.101544

Huang, W., Saydaliev, H.B., Iqbal, W., Irfan, M., 2022a. Measuring the impact of economic policies on CO2emissions: ways to achieve green economic recovery in the post-Covid-19 Era. Clim. Chang. Econ. 13 https://doi.org/10.1142/S2010007822400103

Huang X, Chau KY, Tang YM, Iqbal W (2022b) Business ethics and irrationality in SME during COVID-19: does it impact on sustainable business resilience? Front Environ Sci 10:275. https://doi.org/10.3389/fenvs.2022.870476

Huang X, Huang S, Shui A (2021) Government spending and intergenerational income mobility: Evidence from China. J Econ Behav Organ 191:387–414. https://doi.org/10.1016/j.jebo.2020.09.005

Iqbal S, Taghizadeh-Hesary F, Mohsin M, Iqbal W (2021a). Assessing the role of the green finance index in environmental pollution reduction. Estud. Econ. Apl. 39. https://doi.org/10.25311/etru.0313

Iqbal W, Tang YM, Chau KY, Irfan M, Mohsin M (2021b) Nexus between air pollution and NCOV-2019 in China: application of negative binomial regression analysis. Process Saf Environ Prot 150:557–565. https://doi.org/10.1016/j.psep.2021.04.039

Jin C, Tsai FS, Gu Q, Wu B (2022) Does the porter hypothesis work well in the emission trading schema pilot? Exploring moderating
Xiang H, Chau KY, Iqbal W, Irfan M, Dagar V (2022) Determinants of social commerce usage and online impulse purchase: implications for business and digital revolution. Front Psychol 13:837042. https://doi.org/10.3389/fpsyg.2022.837042

Xiong Q, Sun D (2022) Influence analysis of green finance development impact on carbon emissions: an exploratory study based on fsQCA. Environ. Sci. Pollut. Res. 1–12 https://doi.org/10.1134/S11356-021-18351-2/TABLES/9

Ye J, Al-Fadly A, Huy PQ, Ngo TQ, Hung DDP, Tien NH (2022) The nexus among green financial development and renewable energy: investment in the wake of the Covid-19 pandemic. http://www.tandfonline.com/action/authorSubmission?journalCode=enpol20&page=instructions. https://doi.org/10.1080/1331677X.2022.2035241

Yin L, Wang L, Huang W, Liu S, Yang B, Zheng W (2021) Spatiotemporal analysis of haze in Beijing based on the multi-convolution model. Atmosphere (basel) 12:1408. https://doi.org/10.3390/atmos12111408

York R, Rosa EA, Dietz T (2003) STIRPAT, IPAT and ImPACT: Analytic tools for unpacking the driving forces of environmental impacts. Ecol Econ 46:351–365. https://doi.org/10.1016/S0921-8009(03)00188-5

Yu CH, Wu X, Zhang D, Chen S, Zhao J (2021) Demand for green finance: resolving financing constraints on green innovation in China. Energy Policy 153 https://doi.org/10.1016/j.enpol.2021.112255

Yumei H, Iqbal W, Irfan M, Fatima A (2021a) The dynamics of public spending on sustainable green economy: role of technological innovation and industrial structure effects. Environ Sci Pollut Res 1:1–19. https://doi.org/10.1007/s11356-021-17407-4

Yumei H, Iqbal W, Nurunnabi M, Abbas M, Jingde W, Chaudhry IS (2021b) Nexus between corporate social responsibility and firm’s perceived performance: evidence from SME sector of developing economies. Environ Sci Pollut Res 28:2132–2145. https://doi.org/10.1007/s11356-020-10415-w

Zeng Y, Wang F, Wu J, Zeng Y, Wang F, Wu J (2022) The Impact of green finance on urban haze pollution in China: a technological innovation perspective. Energies 2022, Vol. 15, Page 801 15, 801. https://doi.org/10.3390/EN15030801

Zhang D, Awawdeh AE, Hussain MS, Ngo QT, Hieu VM (2021a) Assessing the nexus mechanism between energy efficiency and green finance. Energy Effic 14:1–18. https://doi.org/10.1007/s12053-021-09987-4

Zhang, D., Mhsin, M., Rasheed, A.K., Chang, Y., Taghizadeh-Hesary, F., 2021c. Public spending and green economic growth in BRI region: mediating role of green finance. Energy Policy 153 https://doi.org/10.1016/j.enpol.2021c.112256

Zheng GW, Siddik AB, Masukujjaman M, Fatema N (2021) Factors affecting the sustainability performance of financial institutions in Bangladesh: the role of green finance. Sustain. 13 https://doi.org/10.3390/su131810165

Zhou Q, Zhu J, Luo S (2022) The impact of fintech innovation on green growth in China: Mediating effect of green finance. Ecol Econ 193:107308. https://doi.org/10.1016/j.ecolecon.2021.107308

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g., a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.