Financial inclusion and its influence on renewable energy consumption-environmental performance: the role of ICTs in China

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Abstract
Financial inclusion means that individuals and businesses can easily avail financial goods and services at an affordable cost. It is widely recognized that financial inclusion can help preserve the environment by increasing the consumption of renewable energy sources. Hence, our basic aim is to investigate whether financial inclusion has any effect on renewable energy consumption and environmental quality in China. To get the estimates of the variables, we have preferred the ARDL model. The estimates of the model confirm that a rise in the number of ATMs and total insurance has a positive impact on renewable energy consumption in China in the long run. Conversely, an increase in the number of ATMs and total insurance negatively affects CO2 emissions in China. In general, we can say that financial inclusion increases renewable energy consumption and reduces CO2 emissions in China. Therefore, by using financial inclusion, policymakers should try to divert the resources towards environmentally friendly consumption and production activities.

Keywords Financial inclusion · ICT · Renewable energy consumption · Environment

Introduction
Over the last few decades, two main problems that have irked the international community are a rise in the demand for energy and an increase in greenhouse gas (GHG) emissions. The key reason behind rising GHG emissions is the heavy reliance on fossil fuels as energy sources (IEA 2017). On one side, the enormous increase in growth-related activities causes the consumption of non-renewable energy sources to rise. On the other side, it has significantly and negatively affected the environmental quality. Therefore, in the twenty-first century, energy security and environmental protection are two significant challenges for the international community, which also have become the central theme of all international forums (Usman et al. 2021a, b, c). Emerging economies depend heavily on the consumption of non-renewable energy sources for economic development; hence, their role is crucial in achieving such targets (Qin and Ozturk 2021).

Renewable energy sources are considered to be clean, green, and carbon-free sources of energy, such as solar, hydro, wind, biogas, and nuclear. However, the cost of such energy projects is high; hence, it requires a big chunk of the initial investment. Therefore, the vibrant and well-functioning financial system with a high inclusion rate can provide necessary funds for the deployment of such energy sources. At the start of the twenty-first century, the concept of financial inclusion got popular after the study of Chibba (2009) suggested financial exclusion as a significant cause of poverty. The definition of financial inclusion by the World Bank implies that all people and firms must be provided with easy and affordable access to financial products and services of all types, including bank accounts, credit and debit cards, saving schemes, insurance facilities, and transactional services (World Bank 2018). Therefore, financial inclusion

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can have long-lasting effects on renewable energy consumption and the environmental performance of countries. While a plethora of studies are available that have analyzed the linkage between environmental quality and financial development, such as Farhani and Ozturk (2015), Acheampong (2019), and Li et al. (2022) for emerging economies and China respectively. However, the literature on the link between financial inclusion and environmental quality is still at its beginning stage because the financial inclusion data is hardly available.

Theoretically, the effects of financial inclusion on renewable energy consumption and environmental quality can be, either way, i.e., negative or positive. The positive effects of financial inclusion can be derived from the fact that financial inclusion makes the financial products and services accessible and affordable to a large population of people, including those in the business community, thereby making the investment in clean and green technologies much easier and less costly. According to IPA (2017), the inclusive financial structure can positively impact environmental quality by increasing the availability, affordability, and implementation of superior ecological practices that help to fight against global warming and environmental pollution. Financial inclusion is specifically important in poor societies where people do not have easy access to capital for investment in clean and green technologies (IPA 2017). Baloch et al. (2021) highlighted that financial exclusion and restrictions such as lack of access to capital, limited financial support from governments, and lack of banking services are the major hurdles in the deployment of solar microgrids. These few examples support the notion that the accessibility and affordability of financial services can help increase the use of renewable energy sources and green technologies, improving environmental quality by avoiding the consumption of carbon-packed energy sources.

On the other hand, the increased accessibility and availability of financial services can instigate manufacturing and industrial activities, causing the CO₂ emissions to rise and consequently contribute to global warming (Tamazian et al. 2009). Furthermore, higher financial inclusion increases the purchasing power of the people, allowing them to consume energy-intensive electronic products like automobiles, microwaves, refrigerators, air-conditioners, dishwashers, and washing machines. The increased use of such items pushes the energy demand upward and, ultimately, CO₂ emissions. Frankel and Romer (1999) posit that an inclusive financial system can spur economic growth, which causes energy demand and CO₂ emissions to rise.

Apart from financial inclusion, ICT has also grabbed the attention of environmentalists and empirics as a mitigating measure of CO₂ emissions. ICT has transformed the economies and revolutionized every sector of the economy. In this era of globalization, foreign direct investment and trading activities are performed mainly by using the internet. Hence, the internet has become an integral part of the economy’s growth process (Usman et al. 2021a, b, c). Moreover, Filos (2010) and Usman et al. (2021a, b, c) observed that ICT helps achieve economic growth without compromising environmental quality because it dematerializes the economy. However, some empirical studies, such as Sadorsky (2012) and Salabuddin and Alam (2015), suggest that increased ICT usage leads to high energy demand, increasing CO₂ emissions. Moreover, the production of ICT-related goods also gives rise to energy demand and toxic emissions (Lange et al. 2020).

China is the fastest-growing emerging economy globally. Among all the countries, China stands first in terms of energy demand. Therefore, pressure is mounting on China from all corners of the world to replace its heavily loaded non-renewable energy structure with renewable energy sources. Renewable energy sources will fulfill China’s energy demand and protect the environment from the harmful effects of CO₂ emissions (Lei et al. 2021). Goal 13 of the sustainable development goals (SDGs) emphasized the need for renewable energy sources to protect the environment. Therefore, to attain the targets of a clean environment and energy security a country like China needs to upsurge the share of renewable energy sources in their total energy, which will positively impact green infrastructure and growth, environmental quality, and quality of life (Zhao et al. 2021).

The ICT sector has contributed significantly to the transformation of the economic structure in China (Usman et al. 2021a, b, c). The Chinese government has recognized the significance of the ICT industry for the sustainability of environmental performance and making effort to improve the ICT industry. The ICT sector has contributed almost 2.5% to economic development from 1985 to 1995 and approximately 7.5% from 1995 to 2003. The ICT industry in China produced an added value equivalent to 10% of GDP during 2010 (Zadek et al. 2010). Moreover, Zhang and Liu (2015) denoted that China was among the top users of ICT products during 2012. While financial inclusion plays a significant role in the formulation of financial reforms that significantly promote green growth. In the 13th Five-Year Plan for Economic and Social Development, the Chinese government mainly focused on the importance of a green economy (Wang et al. 2022).

Against this backdrop, we aim to examine the effect of financial inclusion and ICTs on China’s renewable energy consumption and environmental performance. To our knowledge, this is the first-ever study, exclusively for the Chinese economy, that has tried to analyze the impact of financial inclusion and ICTs on renewable energy consumption and CO₂ emissions in China. No previous study has examined the impact of financial inclusion and ICTs on renewable energy consumption and environmental quality in the short
run and long run. Moreover, previous studies have used panel data analysis that suffered from aggregation bias; whereas, we have used time series analysis free from the problem of aggregation bias. Furthermore, this analysis has focused on short- and long-run estimates against previous studies, which only focus on long-run estimates. To that end, we have relied on the ARDL model, which is an appropriate method if the sample size is small. This research will help environmentalists, development economists, and energy experts in the formulation of such policies that ensure a green economy. This research will help economists in prioritizing green transformation for environmental sustainability.

Model and methods

Following earlier literature of Le et al. (2020), Li et al. (2021), and Usman et al. (2021a, b, c), we assume that the key factors of renewable energy consumption and CO2 emissions are financial inclusion, ICT, GDP, and education. Two empirical models were assembled in the study. Therefore, we begin with the following econometric models:

\[ REC_1 = \pi_0 + \pi_1 FL_1 + \pi_2 ICT_1 + \pi_3 GDP_1 + \pi_4 Education_1 + \epsilon_1 \]  
\[ CO2_1 = \pi_0 + \pi_1 FL_1 + \pi_2 ICT_1 + \pi_3 GDP_1 + \pi_4 Education_1 + \epsilon_1 \]  

(1)  
(2)

Equations (1) and (2) are renewable energy consumption and CO2 emissions models that depend on financial inclusion (FI), information and communications technology (ICT), GDP per capita (GDP), and educational attainments (Education). The rise in financial inclusion and ICT also improve sustainability by increasing their renewable energy consumption and reducing their environmental pollution. Equations (1) and (2) are reported only long-run estimates. In order to measure short-run effects, specifications (1) and (2) must be expressed in an error-correction format as follows:

\[ \Delta REC_t = \pi_0 + \sum_{i=1}^{n} \beta_1 \Delta REC_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta FI_{t-i} + \sum_{i=1}^{n} \beta_1 \Delta ICT_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta FI_{t-i} + \sum_{i=1}^{n} \beta_1 \Delta GDP_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta GDP_{t-i} + \sum_{i=1}^{n} \beta_1 \Delta Education_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta Education_{t-i} + \epsilon_t \]  
\[ \Delta CO2_t = \pi_0 + \sum_{i=1}^{n} \beta_1 \Delta CO2_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta FI_{t-i} + \sum_{i=1}^{n} \beta_1 \Delta ICT_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta ICT_{t-i} + \sum_{i=1}^{n} \beta_1 \Delta GDP_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta GDP_{t-i} + \sum_{i=1}^{n} \beta_1 \Delta Education_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta Education_{t-i} + \sum_{i=1}^{n} \beta_1 \Delta Education_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta Education_{t-i} + \epsilon_t \]  

(3)  
(4)

Specifications (3) and (4) have now resembled the autoregressive distributive lag order (ARDL) model proposed by Pesaran et al. (2001). This method is superior to other time series techniques in many aspects. First of all, this technique simultaneously provides both short and long-run estimates. In Eqs. (3) and (4), the estimates of the first difference variables provide short-run results, and the long-run results are produced via coefficients \( \pi_2 - \pi_3 \) normalized on \( \pi_1 \). However, the validity of long-run results rests on the significant value of bounds \( F \)-test also known as the test of cointegration. Pesaran et al. (2001) developed critical values for the bounds \( F \)-test, and cointegration among the long-run variables is approved if the calculated value of bounds \( F \)-test is greater than the critical value. Moreover, the foremost benefit of applying this method is its ability to deal with the variables of mixed order of integration, i.e., I(0) and I(1). Previous time series estimation techniques such as Engle and Granger (1987) and Johansen and Juselius (1990) can only estimate the variables that are I(1). Therefore, pre-unit root testing is a necessary condition for these time series techniques but not for the bounds testing approach. Another major advantage of this technique is efficient performance in the case of a limited number of observations (Bahmani-Oskooee et al. 2020). Finally, this method can also prove efficient even in the presence of some endogenous repressor variables (Zhang et al. 2022).

Data

The current study intends to explore the influence of financial inclusion and ICT on renewable energy consumption and environmental quality. The study adopted time series data for China for the time period 1995–2019. Table 1 represents the detail of symbols, sources, and definitions of data. In this study, renewable energy consumption (nuclear, renewables, and others) and CO2 emissions (in kilotons) are dependent variables. However, financial inclusion and ICT are the main focused variables. Financial inclusion and ICT have played a critical role in the transformation of the green economy. Following the standard practice (Le et al. 2020), we used Bank branches, ATMs, and insurance as indicators of financial inclusion. Similarly, Usman et al. (2021a, b, c) used internet users as a measure of ICT diffusion. Financial inclusion is measured by three indicators, such as Bank branches (per 100,000 adults), ATMs (per 100,000 adults), and total insurance (measured as a sum of non-life and life insurance premium volume). However, ICT is measured as individuals using the internet in percent of the population. Besides these focused variables, the study used GDP per capita (at constant 2015 US$) and average year of schooling as control variables. Data for this study is taken from the EIA, IMF, and World Bank. In Table 1, the means of REC,
CO₂, BB, ATMs, insurance, internet, GDP per capita, and education are 7.608 quad Btu, 15.65kt, 6.337 (per 100,000 adults), 29.09 (per 100,000 adults), 2.419 premium volume, 24.00%, 15.33 US$, and 11.70 years, respectively, while the standard deviations are 2.134 quad Btu, 0.489kt, 1.885 (per 100,000 adults), 11.65 (per 100,000 adults), 0.854 premium volume, 5.614%, 1.027 US$, and 1.928 years, respectively.

Results and discussion

Testing the stationarity properties of the variables is required for the validation of the statistical findings. To confirm the unit root properties, the study applied Dickey-Fuller generalized least square (DF-GLS) test and Phillips Perron (PP) test. Table 2 displays the findings of ADF and PP tests. We found that in the PP test renewable energy consumption, CO₂ emissions, bank branches, ATMs, total insurance, internet users, and year of schooling contains the issue of a unit root. After taking their first difference, these variables become stationary. However, in the DF-GLS test, CO₂ emissions, bank branches, ATMs, total insurance, internet users, and year of schooling are non-stationary, and after taking the first difference, these variables become stationary. It indicates that variables have a mixed order of integration such as a mixture of the order of integration at I(0) and I(1).

Table 3 displays the effects of financial inclusion and ICT on renewable energy consumption while Table 4 reports the impacts of financial inclusion and ICT on CO₂ emissions. As discussed earlier, the study has used three different proxies to measure the impact of financial inclusion namely bank branches, ATMs, and total insurance. In this regard, three separate models are regressed in Tables 3 and 4. In Table 3, long-run findings of financial inclusion and renewable energy consumption display that the impact of ATMs and insurance is positive on renewable energy consumption while bank branches produce no impact on renewable energy consumption. It implies that a 1% upsurge in ATMs and insurance increases renewable energy consumption by 0.128% and 1.565%, respectively. These findings confirm that financial inclusion is beneficial to promote renewable energy consumption. This is consistent with the study of Wang et al. (2021), who noted that financial inclusion has been recognized as being capable of dropping energy poverty and enhancing renewable energy consumption. This result is also supported by Li et al. (2021), who noted that financial inclusion contributed significantly to bringing financial reforms in China that result in green energy

| Variables | Symbol | Definitions | Mean | Std. Dev | Sources |
|-----------|--------|-------------|------|----------|---------|
| Renewable energy consumption | REC | Nuclear, renewables, and other (quad Btu) | 7.608 | 2.134 | EIA |
| CO₂ emissions | CO₂ | CO₂ emissions (kt) | 15.65 | 0.489 | World bank |
| Bank branches | BB | Bank branches per 100,000 adults | 6.337 | 1.885 | IMF |
| ATMs | ATMs | ATMs per 100,000 adults | 29.09 | 11.65 | IMF |
| Insurance | Insurance | Total insurance (sum of life and non-life insurance premium volume) | 2.419 | 0.854 | IMF |
| Internet users | Internet | Individuals using the internet (% of the population) | 24.00 | 5.614 | World bank |
| GDP per capita | GDP | GDP per capita (constant 2015 US$) | 15.33 | 1.027 | World bank |
| Year of schooling | Education | Average year of schooling | 11.70 | 1.928 | Barro-Lee |

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Table 2 Unit root tests

|       | PP |               |     |     |       |               |     |
|-------|----|---------------|-----|-----|-------|---------------|-----|
|       | I(0) | I(1) | Decision | I(0) | I(1) | Decision |
| REC   | 0.986 | −2.654* | I(1) | −1.996** | I(0) |
| CO₂   | −0.235 | −2.789* | I(1) | −0.189 | −2.985*** | I(1) |
| BB    | −0.023 | −12.35*** | I(1) | −0.866 | −4.123*** | I(1) |
| ATMs  | 1.654 | −2.875* | I(1) | −0.075 | −2.785*** | I(1) |
| Insurance | −0.875 | −9.275*** | I(1) | −0.752 | −7.175*** | I(1) |
| Internet | 1.023 | −2.698* | I(1) | −0.203 | −1.654* | I(1) |
| GDP   | −2.785* | −3.356*** | I(0) | −0.23 | −2.875*** | I(1) |
| Education | 0.689 | −2.688* | I(1) |     |     |       |

Note: ***p < 0.01; **p < 0.05; and *p < 0.1
efficiency. Financial inclusion improves renewable energy consumption by easing household investments in green technology. Financial inclusion improves income levels and has income inequality and poverty-reducing impacts because it enables people to engage in renewable energy consumption (Zhu et al. 2018).

In keeping view the role of ICT, it is observed that the impact of the internet is significant and positive on renewable energy consumption in model 2 and model 3 in the long run. Our finding is also supported by Usman et al. (2021a, b, c), who infer that ICT is reducing conventional energy intensity by increasing renewable energy consumption. This means that ICT is directly and indirectly related to its favorable effect on renewable energy consumption at different levels. This favorable effect of ICT on renewable energy consumption is more substantial for China where smart technology is more dominant.

In the short run, findings display that bank branches and ATMs report insignificant effects on renewable energy consumption; however, total insurance reports a significant and positive impact on renewable energy consumption. In the short run, ICT brings a positive effect on renewable energy consumption in model 2 only. GDP role is completely insignificant in determining renewable energy consumption, while education shows a significant and positive impact on renewable energy consumption in the long run and short run in model 3 only. The lower panel of Table 3 displays the findings of diagnostic tests such as F-statistics, ECM, LM, BP, Ramsey RESET, and CUSUM and CUSUM-sq tests. It is reported that long-run cointegration exists among variables as confirmed by the findings of F-statistics and ECM. No issue of autocorrelation and heteroskedasticity is reported in all three models. Moreover, error terms are normally distributed and stability condition holds in all three models.

Table 4 reports the findings of financial inclusion and ICT on the environment. It is reported that in the long run, ATMs and insurance variables report a significant and negative effect on CO2 emissions while bank branch impact is insignificant on CO2 emissions. It infers that a 1% increase
in ATM holders and insurance result in declining CO$_2$ emissions by 0.002% and 0.173%, respectively. These findings infer that financial inclusion promotion will result in improving environmental quality in the long run. Financial inclusion contributes significantly to influencing environmental quality and expansion of green economic growth (Lesani et al. 2020). Our study reports the positive effect of financial inclusion on environmental quality. Literature supported our findings (Le et al. 2020 and Liu et al. 2021), who argue that financial inclusion provides easy access to individuals and companies to financial products for making feasible green investments. Financial inclusion helps in the mitigation of CO$_2$ emissions through investments in green technological innovations.

However, ICT brings a negative impact on CO$_2$ emissions in model 3 only in the long run. The results revealed that ICT mitigates CO$_2$ emissions in China. This finding is also backed by Usman et al. (2021a, b, c), who infer that ICT is a fundamental pillar of the transition to a knowledge-based green economy. ICT is limiting CO$_2$ emissions through the creation of clean production processes. This also means that ICT has a vital role to play in reducing energy intensity and CO$_2$ emissions. ICT has the capacity to subsidize the achievement of the SDGs by improving social, environmental, and economic performance as they hold great promise to boost green growth and mitigate CO$_2$ emissions. While GDP brings a positive impact on CO$_2$ emissions in model 2 only while education brings a significant and negative impact on CO$_2$ emissions in model 2 and model 3 in the long run.

In the short run, bank branches report a significant and positive effect on CO$_2$ emissions, while ATMs report a significant and negative impact on CO$_2$ emissions. ICT brings significant and negative changes to CO$_2$ emissions in all three models in the short run. GDP reports a significant and

### Table 4 ARDL short- and long-run estimates of CO$_2$ emissions

| Variable          | Model 1 Coefficient | Model 1 t-Stat | Model 2 Coefficient | Model 2 t-Stat | Model 3 Coefficient | Model 3 t-Stat |
|-------------------|---------------------|----------------|---------------------|----------------|---------------------|----------------|
| **Short run**     |                     |                |                     |                |                     |                |
| D(BB)             | 0.175***            | 3.453          |                     |                |                     |                |
| D(ATMS)           | −0.006**            | 2.207          |                     |                |                     |                |
| D(ATMS(-1))       | 0.003               | 1.033          |                     |                |                     |                |
| D(INSURANCE)      | −0.021              | 0.840          |                     |                |                     |                |
| D(INSURANCE(-1))  | −0.089***           | 3.237          |                     |                |                     |                |
| D(INSURANCE(-2))  | −0.112***           | 3.893          |                     |                |                     |                |
| D(INTERNET)       | −0.019**            | 2.067          | −0.024***           | 2.675          | −0.037***           | 4.234          |
| D(INTERNET(-1))   | 0.037***            | 3.824          | 0.011               | 1.423          |                     |                |
| D(GDP)            | 0.019               | 0.930          | 0.036**             | 2.305          | 0.023               | 0.731          |
| D(GDP(-1))        | 0.035               | 1.048          |                     |                |                     |                |
| D(EDUCATION)      | 0.035               | 0.309          | 0.240***            | 2.732          | 0.213**             | 2.411          |
| D(EDUCATION(-1))  | 0.470***            | 3.097          | 0.169**             | 2.227          |                     |                |
| **Long run**      |                     |                |                     |                |                     |                |
| BB                | 1.621               | 0.228          |                     |                |                     |                |
| ATMS              | −0.002**            | 2.075          | −0.173***           | 3.023          |                     |                |
| INSURANCE         | −0.050              | 0.227          | −0.004              | 1.016          | −0.007***           | 3.113          |
| INTERNET          | 0.284               | 0.260          | 0.032***            | 2.648          | 0.021               | 1.091          |
| GDP               | −0.577              | 0.150          | −0.265***           | 7.360          | −0.276***           | 10.33          |
| EDUCATION         | 13.23               | 1.204          | 13.05               | 31.31          | 12.59               | 8.331          |
| C                 |                     |                |                     |                |                     |                |
| **Diagnostics**   |                     |                |                     |                |                     |                |
| F-test            | 3.927*              | 3.854*         | 9.542***            |                |                     |                |
| ECM(-1)           | −0.574**            | 2.239          | −0.476***           | 4.558          | −0.686***           | 4.331          |
| LM                | 1.422               | 1.785          | 1.154               |                |                     |                |
| BP                | 1.542               | 0.485          | 1.254               |                |                     |                |
| RESET             | 0.524               | 1.398          | 0.789               |                |                     |                |
| CUSUM             | S                   | S              | S                   |                |                     |                |
| CUSUM-sq          | S                   | S              | S                   |                |                     |                |

**Note:** ***p < 0.01; **p < 0.05; and *p < 0.1**
positive impact on CO₂ emissions in model 3 only; however, education brings a significant and positive impact on CO₂ emissions in model 2 and model 3 in the short run. In keeping view of the findings of diagnostic tests, it is reported that long-run cointegration exists among financial inclusion, ICT, and CO₂ emissions variables as shown by the coefficient estimates of F-statistics and ECM test. There is no issue of heteroskedasticity, autocorrelation, and the models are stable and normally distributed.

Conclusion and implications

Over the past few decades, the use of ICT has been on the rise in every sector of the economy, and it played an essential role in the economic development of the nations. On one side, it helps to improve the environmental performance of the economy because of using information resources instead of physical. On the other side, it deteriorates the environmental quality due to the increased production of ICT-related products and the energy consumed by these products. Another vital contribution of ICT is in the financial sector, where it has brought the revolution and completely transformed the industry by making it more efficient and cost-effective. In addition to the ICT, financial inclusion has also contributed to the growth of the economy and affected the nation’s environmental performance in one way or another.

It is widely accepted that renewable energy is essential for improving the environmental performance of any nation. Moreover, financial inclusion and ICTs can also play a positive role in increasing carbon-free energy consumption. Therefore, we have investigated the impact of ICT and financial inclusion on China’s environmental quality and renewable energy consumption. The first step in time series analysis is unit root analysis. We have employed two unit root tests, i.e., PP and DF-GLS, and both these tests confirm that our study includes a mixture of I(0) and I(1) variables. Hence, the ARDL model is best suited under such circumstances and provides efficient results. In the renewable energy model, bank branches’ long-run estimate is positive but insignificant. However, the long-run estimates attached to ATMs and insurance are positive and significant. Similarly, the estimates of the internet are positively significant in two of the renewable energy consumption model, whereas positive and insignificant in a third of the renewable energy model. These results imply that financial inclusion and ICT increase renewable energy consumption in China. In the CO₂ emission model, the estimated coefficient of bank branches is positive but insignificant. On the other side, the estimates of ATMs and insurance are significantly negative, confirming that a rise in ATMs and total insurance help improve the environmental quality by lowering CO₂ emissions. However, the estimated coefficients of the internet are negatively significant in only one of the three models. These long-run results are valid only if they pass the criteria of cointegration and the significant values of two cointegration tests such as F-test and ECM confirm that our long-run results are valid.

On the basis of these results, we can draw some important policy implications. First, the policymakers in China should take a cautious approach regarding the inclusion of ICT in pro-environment policies because ICT’s effects on environmental quality are pretty vague, and the policymakers should clearly indicate the cost and benefits of such a policy. On the other side, policymakers should try to promote financial inclusion that would provide easy accessibility to the funds crucial for the deployment of renewable energy projects, thereby causing renewable energy consumption to rise. Furthermore, to attain a superior environment, policymakers must contemplate the synergy effect of financial inclusion in making the policies with regard to development and climate change.

In the future, empirics can analyze the impact of ICT and financial inclusion on environmental quality and renewable energy consumption in other countries and regions. Moreover, the non-linear analysis is more realistic, and future studies should focus on it. The limitation of the study is the short time span of data, and instead of time series, it would be better to combine data for various countries across times that will provide more efficient results.

Author contribution. This idea was given by Jingchao Feng. Jingchao Feng and Qing Sun analyzed the data and wrote the complete paper, while Jingchao Feng and Sidra Sohail read and approved the final version.

Data availability. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval. Not applicable.

Consent to participate. I am free to contact any of the people involved in the research to seek further clarification and information.

Consent to publish. Not applicable.

Competing interests. The authors declare no competing interests.
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