RETRACTED: Environmental concern in the era of digital fiscal inclusion: The evolving role of human capital and ICT in China

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To achieve environmental sustainability, the role of human capital and financial inclusion has been debated in limited empirical studies. Employing a reliable ARDL model approach, this study examines the dynamic link between human capital and ICT, financial inclusion, and CO_2 emissions using the China economy dataset over the period 1998–2020. The vivacious side of human capital shows that literacy rate and average year of schooling curb CO_2 emissions in long run. The results of human capital are also based on facts in magnitude as well as in direction. Also, empirics unfold that digital financial inclusion significantly increases CO_2 emissions. Based on these novel findings, a wide set of economic policies are repaired for environmental quality. Environmental education should be considered at early levels of education. The authorities and policymakers should fix energy-related issues through education. The China government should stimulate the educational sector to conduct a clean and green revolution that acts as a mechanism for a green and clean economy. This study's finding is more effective than the previous unlike empirical studies for policy-making because of the advanced econometric method.

KEYWORDS

financial inclusion, human capital, CO_2 emissions, China, ICT, corporate governance

Introduction and literature review

The problem of climate change has become the crucial agenda of policymakers and authorities. Since the 1980s, many authors have emphasized the upsurge in human resources based on CO_2 emissions (Bilgili et al., 2019; Mahfooz et al., 2020; Liu N. et al., 2022; Lu and Sohail, 2022; Zhao et al., 2022a,b; Zhenyu and Sohail, 2022). Researchers have been doing a lot of empirical research work on the transmission channels of human-induced CO_2 emissions. The present empirical studies offer many social and economic factors such as economic development, globalization, energy consumption, tourism, urbanization, industrialization, technology, capital movements, transportation, FDI, political regime, remittances, financial inclusion, and trade liberalization as the

causes of human capital-based CO_2 emissions (Pata, 2018; Usman et al., 2020). The aforementioned social and economic factors have a significant contribution to existing empirical literature; there is still more need to assess the other applicable aspects such as human capital for sustainable development.

In literature, it has been shown that investment in human capital has many benefits. Human capital positively contributes to higher productivity of labor (Romer, 1990; Becker, 1994; Sohail et al., 2013a, 2019a; Jian et al., 2021; Jiang et al., 2021; Li et al., 2022b) and it is linked with various social externalities such as greater participation of democracy, lower crime rates, and better health (Sianesi and Reenen, 2003). Energy-based studies noted that human capital is a positive impact on renewable energy consumption (Akram et al., 2019; Shahbaz et al., 2019; Adebayo, 2022b; Adebayo et al., 2022b; Awosusi et al., 2022; Du et al., 2022), which in turn improves environmental quality. The study of Goetz et al. (1998) concluded that the USA with good-quality educated population has good quality environmental circumstances because of the level of income and structural transformation. Bano et al. (2018) examined the nexus between carbon emissions and human capital in the case of Pakistan and found that carbon emissions reduction is a result of improvements in human capital in the long term, however, in the short run, there is no relationship. Li and Ouyang (2019) reported that a higher level of human capital increases carbon emissions in the short term, and reduces carbon emissions in the long run. Ahmed and Wang (2019) investigated the influence of human capital on the carbon footprint in the case of India and concluded that a higher level of human capital mitigates the ecological footprint by improving the outcomes of the environment in the short and long term.

Piaggio et al. (2017) argued that energy transitions are one of the structural green processes hence changing CO_2 emissions. Stokey (2015) reported that human capital accumulation is a low process for a green economy, but it has significant impacts on the environment in long run. Yao et al. (2019) stated that OECD countries are not the only contributors to carbon emissions, although they are pioneers in evolving clean alternatives. Madsen et al. (2018) reported that the OECD countries and wealthiest economies of the world have immensely invested in the accumulation of human capital over time.

In developing economies maintenance of economic development along with pollution reduction emissions is a challenge. Pollution emissions are connected with economic based-activities mainly executed by human beings (Šlaus and Jacobs, 2011; Sohail et al., 2015, 2021c, 2022a,c,d; Yat et al., 2018). Economic growth is directly and indirectly responds to human capital. The educated and skilled labor force is used as an input factor in the process of production that is highly accepted in the framework of human capital (Ali et al., 2017; Awan et al., 2021; Mustafa et al., 2022e). Most of the advanced nations have transformed their economy from a labor-based economic structure to a knowledge-based economic structure.

Various studies elaborated on the significance of human capital in diverse perspectives such as human capital that leads to economic development (Bottone and Sena, 2011; Asghar et al., 2012; Sohail et al., 2021a; Adebayo, 2022a; Adebayo et al., 2022a; Khan et al., 2022a,c; Mustafa et al., 2022a,c). Benos and Zotou (2014) infer that human capital is affecting the environment via the green growth process.

Similary, Qadri and Waheed (2014) investigated the influence of human capital on economic development by utilizing labor force and capital stock and reported significant and positive impacts of human capital on economic development. Kumar and Reddy (2007) noted that human capital benefits from improving techniques as well as promoting innovations. Secondary education also contributes to increasing economic growth and poverty reduction (Lee and Chang, 2008; Ali et al., 2017; Solarin et al., 2017; Wang et al., 2017; Yen et al., 2017, 2021; Sohail et al., 2021d). Bodman and Le (2013) noted that human capital positively affects economic development because of innovative, productive, and educated individuals. Human capital also supports increasing consumption of renewable energy because of the awareness, education, and knowledge (Desha et al., 2015). Mehrara et al. (2015) noted that human capital proxied by tertiary education is the major factor in clean energy consumption. Although Sianesi and Reenen (2003) reported that human capital is noble for persons, it is also helpful for society in the context of economic growth and environmental quality.

The role of financial development in the economic growth of a country is undeniable (Le et al., 2019; Sohail et al., 2022d). On the other side, financial inclusion is an integral part of financial development, and its contribution cannot be ignored. The idea of financial inclusion came to the fore in the early 2000s after a study that reckoned financial exclusion as a primary source of poverty and low-living standard (Chibba, 2009; Rasool et al., 2017; Khan et al., 2021, 2022b). Financial inclusion infers that the whole population of the country, including individuals and firms, must have easy access to a wide variety of financial products and services in an appropriate, inexpensive, and reasonable way (World Bank, 2018).

Though several studies have documented the nexus between finance and environmental quality (Sadorsky, 2010; Sohail et al., 2013b, 2019b, 2022b; Yasara et al., 2019; Zhao et al., 2019; Yang et al., 2020; Li et al., 2022), the literature on the impact of financial inclusion on CO_2 emissions is still in its infancy stage. Theoretically, financial inclusion can impact CO_2 emissions, either way, i.e., negative or positive. As already mentioned, financial inclusion makes the availability and accessibility of financial services a lot easier and ultimately makes the investment in green technology more viable. A financial sector with more inclusiveness can improve environmental quality by increasing the convenience, affordability, and implementation of superior environmental standards that can mitigate the harmful impact of the financial sector on climate change

(Muhammad et al., 2014; Mahfooz et al., 2017, 2019; Le et al., 2020; Mustafa et al., 2022b,d,f). A rise in financial inclusiveness is more beneficial for the deprived faction of the society where people do not have access to credit and other financial services that make the deployment of clean energy technology more difficult, which produces much less CO_2 emissions (Sohail et al., 2014b; Renzhi and Baek, 2020; Liu Y. et al., 2022). Baulch and Pramiyanti (2018) also highlighted that financial constraints are the biggest hurdles in deploying solar grids in Vietnam. All these arguments suggest that improved financial inclusion can pave the way for the development of green technology by providing the necessary funds for such projects, crucial for a better environment. Conversely, a rise in financial inclusiveness in the economy may spur the manufacturing and industrial process, polluting the environment by emitting more CO_2 emissions (Sohail et al., 2014a, 2020, 2021b; Qin et al., 2021; Lan et al., 2022; Li et al., 2022a). Similarly, because of the easy availability of funds and credits, consumers can afford more energy-intensive products, which contribute heavily to carbon emissions into the atmosphere.

The complete literature is enormous that each economy now has its empirical literature. While China's literature on human capital and CO_2 emissions are still limited. While previous studies such as Yao et al. (2020) for OECD and Ahmed et al. (2020) for Latin American and Caribbean countries have faced aggregation bias, as noted by Jian et al. (2021). Previous studies by Bano et al. (2018) assumed the linear relationship between human capital and CO_2 emissions but ignored the impact of financial inclusion of carbon emissions in the context of China. The past literature has also found three different empirical findings; human capital has a positive (Wu, 2017), negative (Yao et al., 2020), and insignificant (Dedeoğlu et al., 2021) impact on CO_2 emissions, and infers that findings are inconclusive. While, unlike studies that used a few indicators to measure human capital, we used the government education expenditure, literacy rate, and average year of education to show human capital for suitable and robust analysis. We change the human capital variables in each robustness model.

To reduce the bias, we estimate the effect of financial inclusion and human capital on CO_2 emissions only for China's economy for robustness. The contribution of the study to the empirical literature is renewed, as China's one of the economies that faced the problem of greenhouse gas emissions. China's economy is ranked 1st in CO_2 emitters. This study is more significant for China because the economic growth of China is highly connected to energy consumption and CO_2 emissions. China also signed the agreements of the Kyoto protocol, which motivated a green economy. This study's finding is more effective than the previous unlike empirical studies for policy-making because of the advanced econometric method. The remaining study is organized as; Section 2 describes the model, method, and data. The empirical estimates are offered in Section 3 and Section 4 gives the conclusions and policy.

Model and methods

Theoretical research work argues that human capital formation may also an effective role in environmental quality through numerous transmission channels. Dedeoğlu et al. (2021) noted that human capital formation has a direct and indirect influence on the environment in the long run. Similarly, financial inclusion has reduced transaction costs, influenced saving rates, reduced renewable energy poverty, and improved technological innovation (Beck et al., 2007), which in turn reduces CO_2 emissions. Therefore, in line with Li and Ullah (2022) and Zaidi et al. (2021), we adopt the following model specification:

$$CO_{2,t} = \eta_0 + \eta_1 HC_t + \eta_2 FI_t + \eta_3 GDP_t + \eta_4 Trade_t + \mu_t \quad (1)$$

where t represents country, respectively, CO_2 is the CO_2 emissions, HC is the human capital, and FI is the financial inclusion. We used the GDP per capita (GDP) and trade liberalization (trade) as control variables. If human capital formation role play in the functioning of the green economy, thus η_1 will be to be negative. Regarding empirical and theoretical literature, financial inclusion could have positive and negative impacts on CO_2 emissions, η_2 will be to be positive or negative. Estimation of Eq. (1) yields only long-run estimates. Thus, to include the short-term effect, an error–correction model is employed. An econometric approach that yields the long-run and the short-run effects in one step is that of Pesaran et al. (2001) as follows:

$$\Delta CO_{2,t} = \eta_0 + \sum_{p=1}^{n1} \pi_{1p} \Delta CO_{2,t-p} + \sum_{P=0}^{n2} \pi_{2p}$$
$$\Delta HC_{t-p} + \sum_{p=0}^{n3} \pi_{3p} \Delta FI_{t-p} + \sum_{p=0}^{n4} \pi_{4p} \Delta GDP_{t-p}$$
$$+ \sum_{p=0}^{n5} \pi_{5p} \Delta Trade_{t-p} + \eta_1 CO_{2,t-1} + \eta_2 HC_{t-1}$$
$$+ \eta_3 FI_{t-1} + \eta_4 GDP_{t-1} + \eta_5 Trade_{t-1} + \delta . ECM_{t-1} + \mu_t \quad (2)$$

The error–correction equation (2) is due to Pesaran et al. (2001), where the short-run effects reflected by the η_{1k}, η_{2k}, η_{3k}, η_{4k}, η_{5k}, and η_{6k}. Notation π_{1p}, π_{2p}, π_{3p}, π_{4p}, $and \pi_{5p}$ are the short-run coefficients of the lagged dependent variable, human capital, financial inclusion, GDP, and trade, respectively. The long-run coefficients are η_2, η_3, η_4, η_5 for focused and other control variables. At last, δ displays the speed of adjustment. Using the error correction approach, Pesaran et al. (2001) presented a bounds testing system for cointegration known as the autoregressive distributive lag order (ARDL) model. An earlier study by Ullah et al. (2020) recommends two tests to establish cointegration, such as diagnostic tests (e.g., F-test and ECM). The null hypothesis of F-test among the variables is (Ho: $\eta_1 = \eta_2 = \eta_3 = \eta_4 = \eta_5 = \eta_6 = 0$), but against the alternative hypothesis (H1: $\eta_1 \neq \eta_2 \neq \eta_3 \neq \eta_4 \neq$

TABLE 1 Definitions and sources.

Variables	Symbol	Definition	Sources
CO_2 emissions	CO_2	CO_2 emissions (kt)	World Bank
Education expenditure	EE	Government spending on education, total (% of GDP)	World Bank
Literacy rate	Literacy	Literacy rate, adult total (% of people ages 15 and above)	World Bank
Year of schooling	AYS	Average year of schooling	Barro-Lee
Financial inclusion	FI	ATMs per 100,000 adults is used as a proxy of financial inclusion	IMF
GDP per capita	GDP	GDP per capita (constant 2010 US$)	World Bank
Trade	Trade	Trade (% of GDP)	World Bank

$\eta_5 \neq \eta_6 = 0$). Previous conventional methods require that the variables of the model must be either stationary at I(0) or, at I(1). However, the ARDL model considers the mixture of I(1) and I(0) variables. Another privilege of the ARDL model is that it simultaneously provides long-run and short-run estimates. In addition, a smaller number of observations is a common problem of time-series analysis. The advantage of the ARDL model is that it deals with the issue of a small number of observations and provides unbiased and efficient results. For unit root testing purposes, we have to employ Dickey Fuller–Generalized Least Square (DF–GLS). In the last stage, we also employ some diagnostic and stability tests. To check the problems of serial correlation, functional misspecification, Heteroskedasticity, we have applied LM, Ramsy's RESET, and BP tests. The renowned CUSUM and CUSUM-sq tests are also applied to confirm short-term and long-run coefficient estimates stability.

Data

We collect the sample of China's economy and data spanning from the period 1998 to 2020. Due to data availability, we restrict our human capital to only three variables named education expenditure, literacy rate, and average year of schooling. So, we extract our dataset from the World Development Indicator (WDI) offered by the World Bank, while the average year of schooling dataset is given by Barro and Lee (2019). Financial inclusion data are obtained from IMF. ATMs per 100,000 adults is used as a proxy of financial inclusion. We also employ the extrapolation method for the missing dataset of China's economy. Before estimation, we have converted the GDP and CO_2 emissions variables into a natural logarithm. The details of the variables are also given in Table 1.

Empirical results and discussion

To inspect the level of stationarity of selected variables, we have employed the traditional unit root tests, i.e., ADF and PP tests (Table 2). It is necessary to investigate the integration order of variables. The null hypothesis shows the presence of unit root and confirms that the variables are stationary or non-stationary.

TABLE 2 Unit root tests.

	ADF		PP		Decision	
	I(0)	**I(1)**	**I(0)**	**I(1)**	**ADF**	**PP**
CO_2	−3.442***		−4.748***		I(0)	I(0)
EE	−2.151	−4.381***	−2.489	−4.334***	I(1)	I(1)
Literacy	−1.016	−12.73***	−1.393	−11.43***	I(1)	I(1)
AYS	−0.277	−3.522***	−0.338	−3.552***	I(1)	I(1)
GDP	−1.127	−3.926***	−1.016	−3.888***	I(1)	I(1)
FD	−1.321	−5.148***	−1.633	−5.159***	I(1)	I(1)
Trade	−2.384	−6.748***	−2.431	−6.748***	I(1)	I(1)

***$p < 0.01$.

In our analysis, most of the variables accepted the alternative hypothesis and reveal the variables are stationary at the first difference. ADF and PP show that our model variables have mixed order integration. However, ADF and PP tests highlighted similar outcomes and show the validity of the unit root outcome.

The key aim of the current study is to examine the influence of human capital and financial inclusion on CO_2 emissions for the China's economy. For this purpose, we used three indicators of human capital. Table 3 Panel A revealed the short-run dynamics for all the models such as M1–FF, M2-Literacy, and M3–AYS. The results showed that EE and literacy in models 1 and 2 have an insignificant impact on pollution emissions in the short term. While AYS in model 3 shows a negative significant effect on carbon emissions in China in the short run. Furthermore, the empirical results depict that financial inclusion is positively linked with the carbon emissions in all the models for China. The outcome explored that increase in output growth contributes to carbon emissions in all the models. On the other hand, the turns out indicate that trade opens are statistically significant and negatively correlated with carbon emissions in China except for the M2-literacy model in the short run.

Panel B offered the long-run dynamics for all the models. The results highlight that EE in model 1 indicates an insignificant influence on carbon emissions in the long term. However, in model 2, literacy, and model 3, AYS shows a negative influence on carbon emissions in the long run. Our human capital finding is backed by Yao et al. (2019) who indicate that pollution emissions are reduced by increasing

TABLE 3 ARDL estimates of human capital and CO_2 emissions.

Variable	M1–EE		M2-Literacy		M3–AYS	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Short-run						
D(EE)	−0.008	0.290				
D[EE(−1)]	0.050	1.370				
D[EE(−2)]	−0.051	1.604				
D(LITERACY)			−0.006	1.065		
D(AYS)					−0.152*	2.206
D[AYS(−1)]			0.001		0.003	
D[AYS(−2)]			−0.012		0.113	
D(F1)	0.011***	2.954	0.007**	2.323	0.008**	2.282
D[F1(−1)]	−0.007**	2.066	−0.005*	1.695	−0.005	1.208
D[F1(−2)]					−0.002	0.559
D(GDP)	0.955**	2.269	0.643*	1.820	0.815**	2.120
D[GDP(−1)]	−0.669	1.091	−0.457	0.795	−1.198**	2.190
D[GDP(−2)]	1.814***	2.987	1.266***	3.163	1.267***	3.010
D(TRADE)	−0.006**	2.474	−0.003	1.380	−0.008***	3.039
D[TRADE(−1)]			0.000		0.109	
D[TRADE(−2)]			−0.005*		1.668	
Long-run						
EE	−0.044	0.218				
LITERACY			−0.038*	1.950		
AYS					−0.026**	2.386
FI	0.042*	0.052	0.031	1.110	0.033***	2.765
GDP	2.605***	5.252	1.484	1.129	2.536***	5.731
FD	0.062	1.132	−0.031	1.110	0.033***	2.765
TRADE	0.007	0.357	−0.007	0.488	0.006	0.931
C	−7.061**	2.199	0.235	0.029	−6.631***	2.261
Diagnostic						
F-test	7.302***		4.987***		8.678***	
ECM(−1)	−0.243**	1.989	−0.264**	2.240	−0.372**	2.533
LM	2.231		5.123**		2.264	
BP	1.189		0.996		0.932	
RESET	1.823		1.105		2.241	
CUSUM	US		S		S	
CUSUM-sq	US		S		S	

***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$.

the level of human capital in the long run. The results show that the increase in the education level leads to a reduction in pollution emissions but this effect is relatively small in the context of China's economy. The empirical results recommend that humans play a vital role in environmental quality, especially in the China economy. Education is deliberated the most important factor for developed countries. Human capital is also curbing carbon emissions in China. Findings also show that human capital reduces renewable energy poverty by limiting long-term carbon emissions. Our findings infer that the

educational system of China and fiscal spending are favorable for environmental quality.

The outcome indicates that financial inclusion has a positive influence on carbon emissions only in models 1 and 2 for China. Our results imply that financial inclusion leads to higher CO_2 emissions. Due to increased financial inclusiveness, the availability and accessibility of the range of financial products and services also increase, which allows people to raise their living standards and use more luxury items such as cars, heavy bikes, refrigerators, air-conditioners, etc., which require much

more energy and significantly contributes to the environmental pollution. Similarly, the producers and manufacturers also get easy loans and credits and can perform business transactions more efficiently, which spur economic activities in the country, a significant cause of environmental pollution. Moreover, the results revealed that GDP is positively interlinked with carbon emissions except for M2-literacy. Panel C is offered various diagnostic tests. These results show that all the models did not suffer from any statistical issues.

Panel C displays the numerous statistical diagnostic tests. The ECM value is significant and negative in all models. F-test is also significant and the results show the existence of long-term relationships between human capital, financial inclusion, and CO_2 emissions. Also, results demonstrate that the model did not suffer from multicollinearity, heteroscedastic, and autocorrelation. These test results indicate the stability of all the models. The CUSUM tests indicate stability and Ramsey RESET confirms the correct functional form.

Conclusion and implications

Over the last few decades, many developed economies such as China have achieved rapid economic growth through the excessive use of human and natural resources, thus increasing the environmental pollution in the economy. In China, air and soil pollution has become a severe problem because of industrialization, urbanization, dirty economic growth, and deprived situation of human capital. Therefore, this study examined the impact of human capital and financial inclusion on CO_2 emissions in China from 1998 to 2020. This empirical research reveals that the literacy rate and average year of schooling of China have a negative influence on carbon emissions in the long run. The linear finding shows that human capital improves environmental quality by increasing environmental awareness, renewable energy poverty, and green growth. Several robust analyses and diagnostic tests confirm the human capital reliability of the findings in linear. Furthermore, financial inclusion negatively determines environmental quality by increasing CO_2 emissions in China in the long run. On the other hand, GDP also hurts the environmental quality in China.

Environmental education should be considered at early levels of education. The authorities and policymakers should fix energy-related issues through education. The China government should stimulate the educational sector to conduct a clean and green revolution that acts as a mechanism for a green and clean economy. Furthermore, CO_2 emissions can be controlled through education in China. A highly skilled labor force can use energy sources efficiently that can help in reducing CO_2 emissions. Findings also suggested that decision-making authorities should support financial inclusion through the formulation of legal and regulatory frameworks that ensure a reliable and transparent financial setup. In addition, the knowledge of individuals should be increased regarding financial structure in order to fully utilize the financial services. Financial inclusion in the climate sector should be promoted in order to cope with an intensification of CO_2 emissions. The governments should ensure that the policies of financial inclusion are capable of complementing the welfare policies of the environment and green growth.

The study undergoes numerous limitations. CO_2 emissions is used as measures of environmental pollutant while CH_4, N_2O, and greenhouse gas emissions are ignored. Financial inclusion is only measured through ATMs but ignores other proxies. Panel analysis for China provinces can be conducted. Future research may extend the empirical analysis to China-specific to have an in-depth nexus between education, financial inclusion, and renewable energy consumption (wind, geothermal, solar, biofuel, and biogas). Future research can be conducted using large sample size and up-to-date dataset. Upcoming empirical studies test the green growth hypothesis by enhancing sample size and data period.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

MS and MY: conceptualization, investigation, supervision, writing, reviewing and editing, figure, formal analysis, and literature collection. Both authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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