Urbanization and CO2 emissions in Belt and Road Initiative Economies: Analysis of the mitigating effect of human capital in Asian countries

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Abstract

Balanced and sustainable development is one of the main objectives of the Belt and Road Initiative (BRI). Therefore, considering the role of urbanization and human capital as critical elements for sustainable economic development, we analyze the moderating effect of human capital on the relationship between urbanization and CO2 emissions in Asian member countries of the Belt and Road Initiative. Using the STIRPAT framework and Environmental Kuznets Curve (EKC) hypothesis, we also analyze human capital's linear and nonlinear effects on CO2 emissions in multivariate models, including urbanization, gross domestic product per capita, energy use, and foreign direct investment. We employ the pooled OLS robust standard errors estimator Driscoll-Kraay, the Feasible Generalized Least Squares (FGLS), and the two-stage least square (2SLS) estimators in the case of 30 BRI countries for the period 1980–2019. The results show positive effects of energy and urbanization on CO2 emissions. Moreover, this study reveals that human capital annihilates the positive impact of urbanization on CO2 emissions. We also find that human capital has an inverted U-shaped effect on CO2 emissions. Accordingly, we provide policy implications on the conditional influence of human capital in the urbanization-CO2 emissions nexus for sustainable development in these countries.

JEL code: C21, Q01, Q56

1. Introduction

On the 7th of February, 2022, Alberto Fernandez, president of Argentina, and Xi Jinping, president of China, announced that Argentina has, like many other countries, joined the Belt and Road Initiative (BRI). Through this long-term transcontinental policy and investment program initiative, countries are encouraged to improve connectivity and cooperation, establish and strengthen partnerships, and learn from each other, resulting in diversified and sustainable development. As seen above, one of the main objectives of this Initiative is balanced and sustainable development, meaning a development that tackles climate change and reduces pollution.

Given that CO2 emissions are the main contributor to environmental pollution and global warming (Ozturk, 2017), and urbanization and human capital are among the critical elements of sustainable economic development (Šlaus and Jacobs, 2011; Ahmed, Z, Zafar, MW, Ali, S, et al., 2020), we analyze the relationship between urbanization, human capital, and CO2 emissions using the case of Asian countries members of the Belt and Road Initiative. We considered the case of Asian member countries of the Belt and Road Initiative because, firstly, most Asian countries are facing an increase in their urbanization level. Secondly, the Belt and Road Initiative (BRI) encourages and supports its member countries in setting pro-environmental policies focusing on green development through green finance, green urbanization, and green standards[1] .Thus, considering the rise in global warming and climate change, as well as the Paris Agreement's goal of reducing the global temperature below 2°C (Ullah et al., 2021), the reduction of carbon emission is urgent. To help policymakers overcome this issue, the authors examined the relationship between urbanization and carbon dioxide emissions (Al-Mulali et al., 2015; Kassi et al., 2022).

According to the World Bank (2020), more than half of the world's population lives in urban areas, and that number is growing each day, so cities will play a key role in slowing or stopping global warming and pollution. Hence, it is imperative to analyze the urbanization-CO2 emissions nexus while developing pollution reduction strategies. For Ozturk (2017), CO2 emissions are the most significant cause of pollution and global warming in these countries, so reducing them or identifying their causes would contribute to environmental protection. In so doing, we contribute to the literature on environmental protection and sustainable development by mainly extending the work of Zhang, Yu, and Chen (2017) in three parts. First, we examine the linear and nonlinear relationship between these variables in Asian member countries of BRI. We considered this group of countries because of the role of the BRI in promoting green development, especially in Asian countries, as the first batch of member countries of the Belt and Road Initiative. Second, we include human capital in this analysis, highlighting the role of this variable in reducing CO2 emissions and analyzing the effect of secondary variables like foreign direct investment (FDI). Human capital can be essential in mitigating CO2 emissions and influencing other variables in reducing CO2 emissions (Yao and al., 2020; Wang and al., 2021). And according to Wang and al. (2021) and Churchill and al. (2021), FDI also influence CO2 emissions.

In addition, we examine the conditional effect of human capital on the relationship between urbanization and CO2 emissions. In effect, to combine changing lifestyles and economic practices with environmental preservation, economic growth, and sustainable development, it is vital to educate the population about the importance of climate change. As the population grows, its impact on the environment increases, and this growth of the population means an increase in the urbanization level, the need for water and more valuable resources (land, infrastructures, industry, and energy). Thus, human activities play a huge role in environmental degradation. Government should therefore implement appropriate policies to facilitate the transition from development to sustainable development. Among these policies, one policy can be the improvement of human capital which will help understand the environmental pollution issues and improve energy efficiency (Pablo-Romero et al., 2016). Lastly, we employ three econometrics techniques: The pooled OLS robust standard error estimator Driscoll-Kraay, the feasible generalized least squares (FGLS), and the two-stage least squares (2SLS) estimators. The two first estimators generate robust estimates in the presence of cross-sectional dependence and serial correlation, while the last one deals with endogeneity issues in the models.

The rest of this study is structured as follows. Section 2 presents the theoretical background and the empirical literature. Section 3 describes the data and methods. Section 4 shows and discusses the empirical results. Section 5 concludes the paper by providing policy recommendations and future research areas.

[1] https://eng.yidaiyilu.gov.cn/zchj/qwfb/12479.htm

2. Literature Review

The ecological modernization theory, the compact city theory, and the urban environmental transition theory detail the link between urbanization and CO2 emissions (Poumanyvong and Kaneko, 2010).

For ecological modernization theorists, people with low revenue are only interested in their economic well-being; they care about the environment only after reaching a certain financial level. For them, modernization automatically improves resource efficiency and urban planning (Bekhet and Othman, 2017; Ewing, 2017; York and Rosa, 2003). In the urban environmental transition theory, there are three phases in urbanization. The first phase concerns the improvement of infrastructures. During the second phase, people begin to worry about the environment. In the last stage, people are more interested in the impact of waste on the environment (Marcotullio and Lee, 2003). For compact city theorists (Holden and Norland, 2005; Cereda, 2009), growing cities become more compact, hence advantageous for their citizens and environment (improved facilities, resource-saving technologies). However, for authors like Gren et al. (2018) and Neuman (2005), this theory is only applicable in developed countries.

Several studies have investigated the linear relationship between urbanization and CO2 emissions. For York et al. (2003), and Cole and Neumayer (2004), this link is positive. Wang et al. (2013) and Al-Mulali et al. (2015) found also a positive association. The first one is by using a partial least square (PLS) model, and the second by considering 23 European countries. Behera and Dash (2017) found a positive link between these variables only in high-income countries. For Poumanyvong and Kaneko (2010), urbanization decreases energy consumption in low-income countries and stimulates it in high- and middle-income countries. Kassi et al. (2022) in their analysis also confirmed the positive effect of urbanization on CO2 emissions. For Salim et al. (2019), Sun et al. (2018), and Wang et al. (2019), urbanization increases energy use, leading to high pollution. Kwakwa et al. (2020) also showed a positive link between urbanization and CO2 emissions. Other authors examined the nonlinear link between urbanization and CO2 emissions. They found an inverted U-shaped link between urbanization and CO2 emissions (Martinez-Zarzoso and Maruotti, 2011; Zi et al., 2016; He et al., 2019). Although these analyses have been done regarding the urbanization-CO2 emissions nexus, there is still a gap for Asian member countries of BRI to identify the impact of this Initiative in the fight against CO2 emissions. Moreover, these previous studies ignored the conditional effect of human capital in moderating this nexus across countries. In the human capital theory, education and health increase the productivity and efficiency of people by improving their skills and abilities (Becker, 1962, 1993; Rosen, 1976). Hence, improving education, technical skills and personal resilience will facilitate technological innovation and make growth sustainable. In effect, the economic development of a country is based on human capital through the level of education (Benos and Zotou, 2014). Rist (2008) considers that human capital influences energy efficiency, which reduces pollution. Besides, its improvement permit reducing nonrenewable energy (Yang et al., 2016). For Huo et al. (2020), the urban population and building floor space reduce carbon emissions. Ruza et al. (2022) reveal a nonlinear relationship between human capital and CO2 emissions while analyzing G7 countries. Based on the literature review, we formulate the following hypotheses.

H1: Urbanization contributes to CO2 emissions.

H2: Human capital mitigates the positive effect of urbanization on CO2 emissions

H3: Human capital has an inverted U-shaped effect on CO2 emissions.

3. Data And Methods

3.1 Database

In this work, we examine the data of 30 Asian member countries of the Belt and Road Initiative. [2](BRI) from 1980-to 2019. These data presented in Table 1 are from the World Development Indicators (World Bank, 2021) and the Penn World Table, version 10.0 (Feenstra, Inklaar Timmer, 2015) and have been used according to their availability. There are:

- CO2 emissions which are considered as the level of pollution per inhabitant in the studied countries;
- Human capital index based on years of schooling and returns to education;
- Gross domestic product per capita annual growth which is considered as the growth domestic product per inhabitant in the studied countries;
- Energy use (ENE) which is regarded as the energy consumption per inhabitant in the studied countries;
- Urban population (URB), which is the urban population as a percentage of total population;
- Foreign direct investment (net inflows), which are the new investment inflows less disinvestment in the reporting economy from foreign investors divided by GDP.

Table 1
Variables description

Variables	Description	Unit
CO2	CO2 emission	metric tons per capita
H.C.	Human capital index, based on years of schooling and returns to education	range
GDP/k	Gross domestic product per capita annual growth	percentage
ENE	Energy use	kg of oil equivalent per capita
FDI	Foreign direct investment	percentage of GDP
URB	Urban population as a percentage of total population	percentage
Notes: Data sources, the World Bank database and Penn World Table version 10.0		

3.2 Theoretical model

The theoretical model used in our analysis is the STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology) model, which Dietz and Rosa formulated in 1997. This model, based on the IPAT (Influence, Population, Affluence, and Technology) model proposed by Ehrlich and Holdren (1971), can be written as follows:

$$I_{it} = a_i P_{it}^{b} A_{it}^{c} T_{it}^{d} \mu_{it} \quad (1)$$

In this model, parameter *a* is the constant term, and *b, c* and *d* denote P, A and T parameters. The variable μ represents the error term. The subscript *i (i = 1, 2, …, n)* refers to countries. Meanwhile, the subscript *t (t = 1, 2, …, T)* refers to the time period. By taking the logarithms form of both sides of Eq. (2), we obtain a new linear equation (Eq. (3)) with panel data. This new equation reduces the correlation between variables.

$$\ln I_{it} = \ln a_i + b \ln P_{it} + c \ln A_{it} + d \ln T_{it} + \mu_{it} \quad (2)$$

Following the work of Poumanyvong and Kaneko (2010), Shahbaz et al. (2015), and Rafiq et al. (2016), we incorporate urbanization to the STIRPAT model. The expanded model is rewritten as follows:

$$\ln I_{it} = \ln a_i + b \ln P_{it} + c \ln A_{it} + d \ln T_{it} + \beta \ln urb + \mu_{it} \quad (3)$$

In our empirical models, in line with Assamoi et al. (2020), we adopt carbon dioxide per capita (CO2) as a dependent variable to describe the environmental impact. Affluence is represented by GDP per capita (GDP/k), technology is measured by energy consumption per capita (ENE). Human capital (H.C.) is used to represent population size. Then, we include the lag of the dependent variable and foreign direct investment (FDI), following Chen and al. (2021).

After including the studied variables, we obtain the following model:

$$\ln CO2_{it} = a + \beta_1 \ln CO2_{it-1} + \beta_2 \ln HC_{it} + \beta_3 \ln GDP/k_{it} + \beta_4 \ln ENE_{it} + \beta_5 \ln FDI_{it} + \beta_6 \ln URB_{it} + \mu_{it} \quad (4)$$

Where *a* is the constant term, and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$, the parameters of the variables $\ln CO2_{it-1}, HC_{it}, GDP/k_{it}, ENE_{it}, FDI_{it}, URB_{it}$ respectively. The variable μ_{it} represents the error term. The subscript *i* (i = 1, 2, …, n) refers to countries. Meanwhile, the subscript *t* (t = 1, 2, …, T) refers to the time period.

Furthermore, we examine the conditional effect of human capital on CO2 emissions. Unlike previous studies, we intend to capture the effects of these combinations on CO2, thus showing the role of human capital in this relationship. We obtain the following models:

$$\ln CO2_{it} = \alpha + \gamma_1 \ln CO2_{it-1} + \gamma_2 \ln HC_{it} + \gamma_3 \ln URB_{it} + \gamma_4 \ln HC \times \ln URB_{it} + \gamma_5 \ln GDP/k_{it} + \gamma_6 \ln ENE_{it} + \gamma_7 \ln FDI_{it} + \varepsilon_{it} \quad (6)$$

Where α is the constant term, and $\gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5, \gamma_6, \gamma_7$, the parameters of the variables $\ln CO2_{it-1}, \ln HC_{it}, \ln URB_{it}, \ln HC \times \ln URB_{it}, \ln GDP/k_{it}, \ln ENE_{it}, \ln FDI_{it}$ respectively. The variable ε_{it} represents the error term. The subscript *i* (i = 1, 2, …, n) refers to countries, and the subscript *t* (t = 1, 2, …, T) refers to the time period.

Thus, we analyze whether human capital and urbanization are substitutable $(\gamma_2 \times \gamma_3 < 0 \ and \ \gamma_4 > 0)$ or complementary $(\gamma_4 < 0)$ factors for decreasing CO2 emissions. In particular, human capital accumulation annihilates the detrimental effect of urbanization on environmental quality if $\gamma_2 < 0, \gamma_3 > 0 \ and \ \gamma_4 < 0$.

Conversely, human capital accumulation may thwart any beneficial effect of urbanization on environmental quality if $\gamma_3 < 0 \ and \ \gamma_4 > 0$.

In addition, under the conditional effect of human capital, we compute the marginal effect of urbanization on CO2 emissions as follows:

$$ME_{URB} = \frac{\partial(\ln CO2)}{\partial(\ln URB)} = \gamma_3 + \gamma_4 \times \ln HC \quad (7)$$

We estimate the marginal effect of urbanization (ME_{URB}) on CO2 emissions at the average value of human capital $(\overline{\ln HC})$ of the countries, hereafter:

$$ME_{URB} = \gamma_3 + \gamma_4 \times \overline{\ln HC} \quad (8)$$

Given the average value of human capital, urbanization may enhance the environmental quality of these countries (i.e., reduce CO2 emissions) only if their human capital index exceeds the following threshold:

$$ME_{URB} < 0 \quad if \quad \overline{\ln HC} > (-\frac{\gamma_3}{\gamma_4}), for\ \gamma_4 < 0 \quad and \quad T_{HC} = e^{(-\frac{\gamma_3}{\gamma_4})}$$
$$ME_{URB} < 0 \quad if \quad \overline{\ln HC} < (-\frac{\gamma_3}{\gamma_4}), for\ \gamma_4 > 0 \quad and \quad T_{HC} = e^{(-\frac{\gamma_3}{\gamma_4})} \quad (9)$$

Where:T_{HC} is the threshold level of human capital (H.C.). The symbol is the exponential function of the estimates to derive the threshold level of human capital variable (H.C.) without its logarithmic transformation.

Finally, we investigate the EKC (nonlinear) hypothesis with human capital by incorporating its quadratic term$(\ln HC^2)$, hereafter in model (10):

$$\ln CO2_{it} = \sigma + \varphi_1 \ln CO2_{it-1} + \varphi_2 \ln HC_{it} + \varphi_3 \ln HC_{it}^2 + \varphi_4 \ln GDP/k_{it} + \varphi_5 \ln ENE_{it} + \varphi_6 \ln FDI_{it} + \varphi_7 \ln URB_{it} + \eta_{it} \quad (10)$$

Where σ is the constant term, and $\varphi_1, \varphi_2, \varphi_3, \varphi_4, \varphi_5, \varphi_6, \varphi_7$,the parameters of the variables $\ln CO2_{it-1}, \ln HC_{it}, \ln HC_{it}^2, \ln GDP/k_{it}, \ln ENE_{it}, \ln FDI_{it}, \ln URB_{it}$ respectively. The variable ε_{it}represents the error term. The subscript *i* (i = 1, 2, …, n) refers to countries, and the subscript *t* (t = 1, 2, …, T) refers to the time period.

Hence, we analyze whether human capital has an inverted U-shaped effect on CO2, thus examining the existence of a nonlinear nexus between human capital and CO2 emissions. The quadratic term's coefficient is expected to be negative $(\varphi_3 < 0)$ to denote decreasing levels of CO2 emissions as the level of human capital reaches an optimal threshold in the countries.

Based on model (10), we also derive the marginal impact of human capital (ME_{HC}) on CO2 emissions at its average level $(\overline{\ln HC})$ in the countries, as follows:

$$ME_{HC} = \frac{\partial(\ln CO2)}{\partial(\overline{\ln HC})} = \varphi_2 + 2\varphi_3 \times \overline{\ln HC} \quad (11)$$

Where: ME_{HC} represents the marginal impact of human capital on CO2 emissions in the countries.

3.3. Cross-sectional dependence and panel unit root tests

Before analyzing the link between the different variables, we check the cross dependence of the panel time series by using the cross dependence augmented Dickey-Fuller (CADF) and the cross dependence IPS (CIPS) tests of Breusch-Pagan (1980) and Pesaran (2004, 2007).

3.4. Econometrical methods

In the econometrical model, we apply the feasible generalized least square (FGLS) estimator from Parks (1967) and Kmenta (1986), the pooled OLS robust standard errors estimator developed by Driscoll-Kraay (1998), and the two-stage least squares (2SLS) estimator. The 2SLS estimator is used to address the problem of endogeneity. This estimator is also robust to panel-specific autocorrelation and heteroscedasticity and permits to correct endogeneity and eliminate panel bias. The Driscoll-Kraay and FGLS are used to overcome slope heterogeneity and cross-dependence issues. As the first two estimators do not consider the potential endogeneity of several regressors, we implement the 2SLS estimator, which considers endogeneity, potential heteroscedasticity, and autocorrelation.

[2] These countries are The Republic of Korea, Mongolia, Singapore, Malaysia, Myanmar, Vietnam, Laos, Brunei, Pakistan, Sri Lanka, Bangladesh, Nepal, Maldives, Kazakhstan, Kyrgyzstan, Tajikistan, Thailand, Indonesia, The Philippines, Yemen, Syria, The United Arab Emirates, Kuwait, Turkey, Qatar, Saudi Arabia, Bahrain, Iran, Iraq, and Armenia.

4. Results Of The Study And Discussion

4.1. Descriptive statistics

Table 2 shows the summary statistics of the data. It gives a detailed description of all the variables analyzed in this work. The investigated period is 39 years, and the number of countries is 30. On average, these countries' CO2 emissions rate is 0.32, while the urbanization rate is 1.65. In addition, the level of infrastructures (3.44) and the energy consumption (2.98) are high in the studied countries. Regarding the variables of human capital (H.C.) and FDI, their average levels are 0.38 and 0.22 in the studied countries.

Table 2
Descriptive statistics

	LNCO2	LNHC	LNGDP/K	LNENE	LNFDI	LNURB
Mean	0.234	0.316	0.552	2.962	-0.031	1.621
Median	0.232	0.325	0.627	2.839	0.102	1.657
Maximum	1.793	0.560	1.694	4.345	1.643	2.000
Minimum	-1.672	0.019	-1.219	1.973	-4.555	0.623
Std. Dev.	0.691	0.127	0.395	0.506	0.883	0.255
Jarque-Bera	13.401	28.713	300.518	53.635	360.774	35.569
Probability	0.001	0.000	0.000	0.000	0.000	0.000
Notes: We applied the logarithmic transformation to all the variables						

Table 3 highlights the link among the studied variables. It shows a positive and significant correlation between CO2, H.C., ENE, FDI, URB, and a non-significant between CO2 and GDP/k.

Table 3
Correlation matrix

Correlation Probability	lnCO2	lnHC	lnGDP/K	lnENE	lnFDI	lnURB
lnCO2	1.000					
lnHC	0.468*** (0.000)	1.000				
lnGDP/K	0.021 (0.577)	0.098*** (0.009)	1.000			
lnENE	0.934*** (0.000)	0.486*** (0.000)	-0.055 (0.140)	1.000		
lnFDI	0.327*** (0.000)	0.480*** (0.000)	0.125*** (0.001)	0.326*** (0.000)	1.000	
lnURB	0.908*** (0.000)	0.474*** (0.000)	0.068* (0.069)	0.824*** (0.0000)	0.334*** (0.000)	1.000
Note: *, **, *** denote the statistical significance at the 10%, 5%, and 1% levels, respectively.						

4.2 Estimation analysis

4.2.1 Cross dependence and second-generation panel unit root test

Table 4 shows the existence of cross-sectional dependence among the panel time series. The lower probability values of the three tests statistics lead to the rejection of the null hypothesis of cross-sectional independence at the 5% level of significance. The second-generation panel unit tests CADF and CIPS results Table 5 show that the variables are stationary at the first difference at the 1% level of significance.

Table 4
The cross-dependence tests

	lnCO2	lnHC	lnGDP/K	lnENE	lnFDI	lnURB
Breusch-Pagan LM	6613.35***	15354.64***	796.57***	6400.75***	2809.21***	16661.85***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Pesaran scaled LM	208.45***	504.81***	11.24***	209.36***	79.476***	549.125***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Pesaran CD	25.36***	118.72***	4.81***	49.58***	41.781***	34.391***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Note: *, **, *** denote the statistical significance at the 10%, 5%, and 1% levels, respectively.						

Table 5
The second-generation panel unit root tests

	CADF		CIPS	
	Level	First difference	Level	First difference
lnCO2	-2.289***	-4.379***	-2.351***	-5.900***
lnHC	-0.699	-2402**	0.302	-5.056***
lnGDP/K	-3.532***	-6.020***	-4.527***	-5.190***
lnENE	-1.799	-5.355***	-2.631***	-5.897***
lnFDI	-3.591***	-6.047***	-4.644***	-6.190***
lnURB	-1.929	-2.002*	-1.204	-2.412***
Note: *, **, *** denote the statistical significance at the 10%, 5%, and 1% levels, respectively				

We use the pooled OLS Driscoll-Kraay, and the FGLS estimators to deal with the cross-dependence and serial correlation. The FGLS estimator is suitable when T is greater than N for all groups of countries. The FGLS results are used to confirm the results of the Driscoll-Kraay estimation. The next tables (Table 6, Table 7, Table 8) present the results of the different estimations. The coefficients estimated from FGLS, pooled OLS robust standard errors estimator Driscoll-Kraay, and 2SLS methods can be interpreted as elasticity as all the variables are expressed in natural logarithms. All the test estimators provide similar results in terms of statistical significance and signs of the coefficients.

Table 6
The linear approach

Variables	FGLS		Driscoll-Kraay		2SLS	
	Coef.	P-value	Coef.	P-value	Coef.	P-value
$\ln CO2_{it-1}$	0.756***	0.000	0.617***	0.000	0.815***	0.000
lnHC	-0.097**	0.030	-0.179*	0.066	-0.152***	0.001
lnGDP/K	0.007	0.569	0.046	0.210	0.017	0.195
lnENE	0.034***	0.000	0.036**	0.018	0.028***	0.000
lnFDI	0.008	0.238	0.009	0.402	0.014	0.440
lnURB	0.588***	0.000	0.887***	0.000	0.457***	0.000
Constant	-0.945***	0.000	-1.388***	0.000	-0.727***	0.000
Note: *, **, *** denote the statistical significance at the 10%, 5%, and 1% levels, respectively.						

The pooled OLS robust standard errors Driscoll-Kraay estimator results show that human capital (H.C.) negatively affects CO2 emissions, and a 1% increase in H.C. decreases CO2 by 0.097%. Also, urbanization (URB) and energy consumption (ENE) positively affect CO2 emissions. That means a 1% increase in URB and ENE increase CO2 by 0.59% and 0.03%, respectively. The use of the FGLS estimator provided additional confirmation. It indicates the robustness of the main findings of this research. These results are consistent with the work of Saidi and Hammami (2015) and Aye and Edoja (2017), who indicated a positive relationship between energy consumption and CO2 emissions.

Table 7 reports that the coefficients of urbanization are positive in all three estimation techniques, and each of these is significant at the 1% significance level. So, urbanization has a positive and significant effect on CO2 emissions, and a 1% increase in urbanization increase CO2 emissions by 0.756 percent, 0.943 percent, and 0.592 percent in the FGLS, Driscoll-Kraay, and 2SLS estimations. This finding supports the hypothesis (H1) of the positive effect of urbanization on CO2 emissions and is consistent with most previous studies (Al-Mulali et al., 2015; Li and Lin, 2015; Behera and Dash, 2017). In effect, with urbanization, we have an increase in energy consumption with the use of fossil fuels energy, mainly by households and industry, contributing to the rise of CO2 emissions. Besides, the results show that combining human capital and urbanization negatively and significantly affects CO2 emissions. Thus, a 1 percent increase $\ln HC \times \ln URB$reduces CO2 by 0.751%, 0.834%, and 0.682%, respectively. This finding confirms the hypothesis (H2), revealing that human capital mitigates the detrimental effect of urbanization on environmental quality in the studied countries. This result confirms the analysis of Becker (1962, 1993) and Rist (2008), who considered that human capital improves skills and abilities which contribute to energy efficiency, hence sustainable development.

In addition, Table 7 shows that urbanization has a positive marginal effect (ME_{URB})on CO2 emissions in the countries, which are robust and consistent across the different estimators. The positive marginal impact of urbanization on CO2 emissions results from the fact that the average level of human capital in these countries is below the optimal threshold (T_{HC})calculated in Table 7. Table 8 reports that the square of human capital has a negative and significant effect on CO2 emissions. For instance, a 1% increase of $InHC^2$ reduces CO2 by 1.061%, 1.045%, 0.878%, respectively. Besides, the impact of $InHC^2$ on CO2 emissions (1.061) is higher than those of *InHC* on CO2 emissions (0.097).

Table 7
Results of the conditional effect of human capital on the urbanization-CO2 emissions nexus

Variables	**FGLS**		**Driscoll-Kraay**		**2SLS**	
	Coef.	P-value	Coef.	P-value	Coef.	P-value
$\ln CO2_{it-1}$	0.755***	0.000	0.628***	0.000	0.819***	0.000
lnHC	1.129***	0.000	1.252**	0.011	0.987***	0.000
lnURB	0.758***	0.000	0.943***	0.000	0.592***	0.000
$\ln HC \times \ln URB$	-0.751***	0.000	-0.834*	0.087	-0.682***	0.000
lnGDP/K	-0.001	0.937	-0.360	0.510	0.005	0.691
lnENE	0.036***	0.000	0.033**	0.015	0.031***	0.000
lnFDI	0.009	0.163	0.012	0.293	0.014	0.361
Constant	-1.211***	0.000	-1.478***	0.000	-0.944***	0.000
ME_{URB}	0.521		0.679		0.376	
T_{HC}	2.744		3.098		2.382	

Note: Following equations (8) and (9), $ME_{URB} \quad and \quad T_{HC}$ are the computed marginal impact of urbanization on CO2 emissions, and the threshold level of human capital, respectively. The symbols *, **, *** denote the statistical significance at the 10%, 5%, and 1% levels, respectively.

Thus, our results confirm the hypothesis (H3) on the fact that human capital has an inverted U-shaped effect on CO2 emissions. Basically, the more educated people are, the more concerned they are about environmental protection and climate change. As a result, they utilize green transportation, such as hybrid vehicles. This finding follows Lan et al.'s (2011) work by showing the positive influence of human capital on environmental protection.

The positive link between energy use and CO2 emissions highlights the fact that there is a high use of coal, petroleum, and gas in the studied countries. This reliance on fossil fuels in daily activities causes massive smoke expulsion from factories and households, which boosts CO2 emissions. It also shows that even though these countries are part of BRI, sustainable environmental policies suggested by this Initiative are not yet implemented in these economies. Regarding this situation, policymakers should enforce policies to move from fossil fuel energy to clean energy, such as biofuels and solar energy. These policies should include the construction of low-carbon infrastructures such as railways, metros or tramways in line with green policies, which will contribute to reducing carbon emissions.

Table 8
Results of the nonlinear effect of human capital on CO2 emissions

Variables	FGLS		Driscoll-Kraay		2SLS	
	Coef.	P-value	Coef.	P-value	Coef.	P-value
$\ln CO2_{it-1}$	0.732***	0.000	0.621***	0.000	0.811***	0.000
lnHC	0.478***	0.001	0.380**	0.012	0.326***	0.009
$\ln HC^2$	-1.061***	0.000	-1.045*	0.052	-0.878***	0.000
lnGDP/K	0.001	0.968	0.040	0.161	0.010	0.420
lnENE	0.031***	0.000	0.032**	0.020	0.025***	0.000
lnFDI	0.010	0.135	0.012	0.291	0.017	0.15
lnURB	0.645***	0.000	0.844***	0.000	0.464***	0.000
Constant	-1.078***	0.000	-1.360***	0.000	-0.774***	0.000
ME_{HC}	-0.193		-0.280		-0.229	

Note: Following Eq. (11) ME_{HC} is the computed marginal impact of human capital on CO2 emissions. The symbols *, **, *** denote the statistical significance at the 10%, 5%, and 1% levels, respectively.

The growth of urban areas increases economic activities, which generate higher demands for transportation and household equipment (heating installation and electric appliances). Besides, the construction of public infrastructures (highways, bridges, and sewage systems) uses a lot of energy and generates additional carbon emissions. These factors contribute to an increase in carbon emissions. Hence, these countries' policymakers should consider creating smart cities that use energy-efficient equipment (electric household equipment). Furthermore, government officials should encourage urban residents to adopt a healthier lifestyle incorporating energy conservation and clean energy. Renewable energy consumption in daily activities and good governance practices in urban areas are also key drivers of sustainable growth across countries (Kassi et al., 2020; Kassi et al., 2021).

The negative impacts of $\ln HC \times \ln URB$ and $\ln HC^2$ on CO2 show that the level of education contributes to the protection of the environment, especially in urban areas. Indeed, educated people will have better knowledge regarding the impact of pollution on climate change. Hence, they will adapt their behavior in order to contribute to environment protection. Policymakers should implement policies that promote human capital accumulation in their urbanization strategies for sustainable development across countries.

5. Conclusion

This study highlights the roles of urbanization and human capital on CO2 emissions. In particular, we analyze the conditional effect of human capital on the urbanization-CO2 emissions nexus in Asian member countries of the Belt and Road Initiative during the 1980–2019 period. We employed the robust standard errors of Driscoll-Kraay (1998) with the pooled OLS, the FGLS (Parks 1967; Kmenta 1986), and the 2SLS estimators.

We found a negative effect of human capital on CO2 emissions and positive impacts of energy consumption and urbanization on CO2 emissions. In addition, our results showed that human capital annihilated the detrimental effect of urbanization on the environment. In effect, the combination of human capital and urbanization reduces CO2 emissions. This result reveals that human capital and urbanization are complementary levers in reducing CO2 emissions across countries. Finally, we found that human capital had an inverted U-shaped effect on CO2 emissions in the studied countries. Similar values of coefficients for all estimations confirm the robustness of the results.

The negative relationship between human capital and CO2 emissions and its mitigating effect on the urbanization-CO2 emissions nexus highlight the beneficial effect of education in the fight against pollution. So, policymakers should invest more in education, especially in urban areas, by adding topics related to environmental degradation and launching training programs to raise awareness among people in these countries. Besides, electronic and print media can teach the importance of sustainable living and working habits and encourage citizens to use solar energy, renewable energy products, energy-saving gadgets and facilities. Governments can also subsidize low-energy consuming enterprises by reducing the price of pro-environmental items. Countries, through BRI, can also promote sustainable urbanization through education on green policies and instruments, by setting efficient public transportation systems (bus, metro, tramways) and by promoting green products and services. This system will reduce traffic congestion, overcrowding, and pollution. Policymakers should also build cities with sky-high buildings and short distances between workplaces and residential areas. These cities will permit reducing energy use and emissions. As part of the BRI, these countries should develop a renewable energy funding mechanism to improve their energy supply in order to achieve long-term economic sustainability.

As a final point, the study has some limitations. Future studies should consider governance indicators like corruption, which indirectly impact urbanization and human capital through public spending and policy implementation. Moreover, studies can expand this work by including other dimensions, such as health or poverty.

Declarations

Ethical Approval

Not applicable

Consent to participate

Not applicable

Consent to Publish

Not applicable

Availability of data and material

The datasets generated and/or analyzed during the current study are from the 2021 World Development Indicators, and the Penn World Table, version 10.0.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

Conceptualization: TYG; Methodology: TYG; Formal analysis and investigation: TYG; Writing - original draft preparation: TYG; Writing, review and editing: DFK; Project administration: TYG; Software: OK; Supervision: TYG.

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