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The dynamic relationship between trade openness, foreign direct investment, capital formation, and industrial economic growth in China: new evidence from ARDL bounds testing approach

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The objective of this research is to use annual data from 1990 to 2021 to examine the long- and short-run dynamic relationships among China's trade openness (TRO), foreign direct investment (FDI), capital formation (K), and industrial economic growth (IEG) using the Autoregressive Distribution Lag (ARDL) method. Firstly, the results of the ARDL co-integration tests show that there is a long-run co-integration relationship among TRO, FDI, K , and IEG. Secondly, from a path of influence perspective, both the long- and short-run relationships are almost the same. Specifically, TRO, FDI, and K all have positive effects on IEG and vice versa, which supports the feedback hypothesis. However, contrary to the short-run relationship, TRO and K have a small negative effect on IEG, but this is not statistically significant. Finally, K and TRO positively affect FDI, while FDI negatively affects K , although the effect is minimal and negligible at the 10% significance level. On the contrary, they are not statistically significant in the long run. These results support the theory that technological innovation in the trade, investment and capital system based on economic and market capital can stimulate the development of China's industrial economy.

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Introduction

For the past few years, with the rapid development of trade opening and economic deepening, trade openness and foreign direct investment (FDI) are widely regarded by countries around the world as key catalysts for rapid economic growth. FDI is an important source of capital for domestic industrial investment in countries around the world, and it promotes domestic capital formation (Mohammed and Ruslee, 2015). Therefore, FDI and trade openness play a vital role in capital formation in the economic development of developing countries. However, economists around the world have different opinions on whether the introduction of FDI will promote economic growth. In the 2012 United Nations Conference on Trade and Development (UNCTAD), it was discussed that FDI is the driving force of sustainable economic development, while the World Trade Organization also emphasized that trade openness is another driving force of sustainable economic development, especially for developing countries. Meanwhile, in the World Report 2021: Global Investment Trends and Prospects from the UNCTAD, it is also stated that FDI and trade openness are complementary and have a positive effect on economic growth. Therefore, for economic growth, FDI inflows are both advantageous growth and advantageous trade, and vice versa (Osuji, 2015; Fofana et al., 2019).

Since the opening up and reform, with increased FDI inflows and trade openness, China has been one of the fastest-growing economies in the world (Peters et al., 2007). Over the past decades, China's sustained and steady economic growth has attracted large inflows of FDI (Hou et al., 2021). From 1991 to 2020, China's FDI inflows, industrial economy and GDP grew at an average annual rate of 15%, 10.4%, and 50%, respectively. Among them, China's total FDI inflows were US\$42 billion in 2000 and US\$243.7 billion in 2010, an increase of 480% compared with 2000. 2020 FDI inflows totaled US\$253.1 billion, an increase of 3.9% and 7.5% compared with 2010 and 2018, respectively. Nowadays, due to the current state of economic globalization, China is now the recipient of the second-largest amount of FDI from developing nations, behind the United States. However, while China's foreign trade and FDI inflows have led to the rapid development of its industrial economy, the rate of technological advancement has been relatively slow compared to that of developed countries, and industrial economic growth has become overly dependent on large inputs of capital, labor and resources, resulting in increasingly serious problems of resource shortages and environmental degradation. (Kathuria, 2001). Therefore, how to make reasonable guidance on the FDI industry layout and trade opening structure adjustment, and give full play to the transformation of China's domestic industry and national economic growth mode driven by trade opening and FDI has a crucial role (Vikas, 2014).

The remaining part of the paper is organized as follows: section "Literature review" provides a brief literature review, section "Model construction and data sources" presents the model construction and data sources, section "Empirical analysis and discussion of results" provides the empirical analysis and discussion of the results, and section "Conclusion and policy implications" presents the conclusion and some policy implications of the article.

Literature review

Scientific and technological progress is a necessary precondition for the sustainable development of the national economy. Therefore, in accelerating the transformation of China's economic growth mode, it is necessary to fundamentally change the extensive economic growth mode that relies too much on factor

input, so that scientific and technological progress becomes the dominant force in economic growth. Regarding the issue of how to achieve technological progress, Mohammed and Ruslee (2015) and Kathuria (2001) argue that under the conditions of an open economy, FDI will not only increase the productivity of a country's domestic enterprises, but also have a positive spillover effect on the economy. At the same time, it will be accompanied by scientific and technological progress and the cultivation of talents, and the knowledge innovation activities of other countries will also directly or indirectly affect the country's technological progress in the form of knowledge spillovers through various transmission mechanisms, in which, international trade and FDI are the main channels of knowledge diffusion and spillover between countries. Liu and Burrige et al. (2002) suggest that under China's open economic policy, economic development, foreign trade, and FDI are mutually reinforcing. Meanwhile, it is also found that if the interaction between FDI, economic growth and foreign trade is not considered, negative spillover effects may occur. Blyde (2004) has emphasized the proliferation effect of international trade on industrial technology and argues that foreign trade can promote domestic industrial development and technological progress. It is also found that the foreign trade between Latin American countries is an additional mechanism, and through this mechanism, industrial technology indirectly spread to the entire Latin American region. Although it is generally believed that FDI can make up for the host country's domestic capital investment and capital reserve gap, a more important point is that the externalities of production efficiency and economic spillover effects it brings will play an important role in promoting the progress of science and technology in the host country. Obviously, this result has not been confirmed. Kalai and Zghidi (2019) have pointed out that trade openness and FDI can promote the economic growth and technological progress of the host country. However, Sadni-Jallab and Gbakou (2009) and Ali and Mingque (2018) argue that FDI has no obvious influence on the technological progress and economic growth of the host country, nor does it depend on the degree of trade openness and per capita income (Gür, 2016). But the impact of FDI on economic growth depends on macroeconomic stability of the host country. In most macroeconomic studies, there is an obvious positive correlation between economic growth and government scale indicators. In contrast, Vikas (2014) suggests that under the conditions of an open economy, as the degree of capital openness increases, it may cause the outflow of Indian domestic capital. Therefore, there is a negative spillover effect between foreign trade, capital opening and government scale, and the impact of FDI on government scale is not obvious. On the contrary, Osuji (2015) and Fofana et al. (2019) argue that FDI inflows have had a beneficial effect on the development of the economy both in the short- and long-term. It is also found that a single foreign trade economy is not enough to affect economic growth. It is necessary to promote the integration of FDI inflows with the national economy and promote the reform of foreign trade strategies to achieve sustainable economic growth. Furthermore, Emmanuel et al. (2020) suggest that Ghana's FDI, inflation and trade liberalization have an asymmetric effect. The study also found that foreign trade has a positive spillover effect on economic growth, while FDI and inflation have a negative effect on economic growth, but they are not statistically significant.

In summary, previous studies have mainly discussed trade openness, FDI and economic growth, and have found both positive and a negative impact on economic growth. However, no matter from the perspective of theoretical analysis or empirical analysis, there is no consensus on the impact of trade openness and FDI on economic growth, so the research system needs to be

further tested and improved. As far as China is concerned, there are few research topics in this area, especially the impact of trade openness and FDI on China's capital formation and industrial economic growth. It is difficult to reveal the industrial restructuring and government capital formation effects arising from trade opening and FDI because studies for China are more based on national or regional perspectives, ignoring the effects of foreign trade or FDI on industrial economic growth patterns. In recent years, in the context of globalization, China's foreign trade has been completed mainly in industrial enterprises, and incoming direct investment and government capital formation in China also act mainly in the industrial sector, by which they have an impact on the allocation of resources between different industries within the industrial sector, as it is increasingly linked to the rest of the world economy. If the role of trade opening, FDI and capital formation on economic growth patterns is examined only from an aggregate or regional perspective, the impact of trade opening, FDI and capital formation on the transformation of China's economic growth patterns and long-term sustainable development may be underestimated. Therefore, in order to gain insight into the long-run and short-run dynamic relationships between China's trade openness, FDI, capital formation, and industrial economic growth, this study uses autoregressive distribution lag-error correction matter (ARDL-ECM) and boundary co-integration test method for analysis and puts forward corresponding hypotheses and policy recommendations on this basis.

Hypothesis 1: Trade openness and FDI have positive effects on industrial economic growth in China.

Hypothesis 2: Trade opening, FDI and capital formation will synergistically contribute to industrial economic growth in China based on external spillovers such as inflation, labor and technological innovation.

Model construction and data sources

In this study, we consider FDI as an essential part of production and economic output and analyse the external effects of FDI on industrial economic output through the extended Cobb-Douglas production function model (Ramirez, 2000). In order to adopt this model, we divide industrial capital investment into internal capital formation in the economy and FDI capital and trade openness. We also need to control the impact of endogenous variables such as macroeconomic policies, labor, and technological innovation on industrial economic output, so as to reduce the problem of ignoring variable deviations (Osuji, 2015). Therefore, the theoretical model is as follows:

$$IEG_t = Af(TRO_t, FDI_t, K_t, X_t) \tag{1}$$

where *A* means production efficiency; *IEG* means industrial economic output; *TRO* means open trade; *FDI* means foreign direct investment; *K* means capital formation; *X* means other control variables (such as inflation rate, labor force and technological innovation). According to Ramirez (2000), the stock of FDI can directly stimulate economic growth, rather than the flow of FDI. This means that in the economic system we have to consider changes in the actual stock of FDI rather than changes in the flow.

ARDL bounds testing for co-integration. Pesaran and Shin (1999) have proposed the ARDL bounds test theory, which mainly uses the Wald statistics in the model to determine whether the variable lag co-efficient is significant. Pesaran et al. (2001) and Pesaran and Shin (1999), based on the ARDL bounds test theory and the VAR(*p*) model, have successively proposed the ARDL co-integration method to study the long- and short-run dynamical

relationship of various variables (such as TRO, FDI, *K*, and IEG). Compared to the traditional co-integration model, the ARDL co-integration model has a number of advantages. Firstly, ARDL does not require the implementation of the same integrating sequence for all variables in the model (we can use the 0 order or I (0) integration of the data variable and the 1 order or I (1) integration for the analysis) (Mohammed and Ruslee, 2015; Hao, 2021). Secondly, the ARDL co-integration method is more suitable for sequence data with small sample size, and the processing and interpretation of the data in the analysis process is relatively simple. Finally, the ARDL co-integration method can provide impartial estimations of long-run relationships and long-run parameters of variables (Sloboda, 2004). Therefore, the co-integration model based on ARDL bounds test is as follows:

$$\begin{aligned} \Delta IEG_t = & \alpha + \sum_{i=1}^p \beta_i \Delta IEG_{t-1} + \sum_{i=0}^q \gamma_i \Delta TRO_{t-1} + \sum_{i=0}^r \delta_i \Delta FDI_{t-1} \\ & + \sum_{i=0}^m \lambda_i \Delta K_{t-1} + \sum_{i=0}^n \omega_i \Delta X_{t-1} + \theta_1 IEG_{t-1} + \theta_2 TRO_{t-1} \\ & + \theta_3 FDI_{t-1} + \theta_4 K_{t-1} + \theta_5 X_{t-1} + \varepsilon_t \end{aligned} \tag{2}$$

$$\begin{aligned} \Delta TRO_t = & \alpha + \sum_{i=1}^p \beta_i \Delta TRO_{t-1} + \sum_{i=0}^q \gamma_i \Delta IEG_{t-1} + \sum_{i=0}^r \delta_i \Delta FDI_{t-1} \\ & + \sum_{i=0}^m \lambda_i \Delta K_{t-1} + \sum_{i=0}^n \omega_i \Delta X_{t-1} + \theta_1 TRO_{t-1} + \theta_2 IEG_{t-1} \\ & + \theta_3 FDI_{t-1} + \theta_4 K_{t-1} + \theta_5 X_{t-1} + \varepsilon_t \end{aligned} \tag{3}$$

$$\begin{aligned} \Delta FDI_t = & \alpha + \sum_{i=1}^p \beta_i \Delta FDI_{t-1} + \sum_{i=0}^q \gamma_i \Delta IEG_{t-1} + \sum_{i=0}^r \delta_i \Delta TRO_{t-1} \\ & + \sum_{i=0}^m \lambda_i \Delta K_{t-1} + \sum_{i=0}^n \omega_i \Delta X_{t-1} + \theta_1 FDI_{t-1} + \theta_2 IEG_{t-1} \\ & + \theta_3 TRO_{t-1} + \theta_4 K_{t-1} + \theta_5 X_{t-1} + \varepsilon_t \end{aligned} \tag{4}$$

$$\begin{aligned} \Delta K_t = & \alpha + \sum_{i=1}^p \beta_i \Delta K_{t-1} + \sum_{i=0}^q \gamma_i \Delta IEG_{t-1} + \sum_{i=0}^r \delta_i \Delta TRO_{t-1} \\ & + \sum_{i=0}^m \lambda_i \Delta FDI_{t-1} + \sum_{i=0}^n \omega_i \Delta X_{t-1} + \theta_1 K_{t-1} + \theta_2 IEG_{t-1} \\ & + \theta_3 TRO_{t-1} + \theta_4 FDI_{t-1} + \theta_5 X_{t-1} + \varepsilon_t \end{aligned} \tag{5}$$

where $\theta_i = \sum_{j=1}^k A_j - I$ and $\beta_i = \gamma_i = \delta_i = \lambda_i = -\sum_{j=i+1}^k A_j$; ε_t represent the random disturbance term of the ARDL co-integration model and follow the common white Gaussian process with mean and constant variance of zero. The objective of the exercise is to determine whether there is a long-run relationship between the IEG's ARDL co-integration model and the variables (TRO, FDI, *K*, and other control variables *X*), as well as the rank and the short-run adjustment speed ($\beta_i, \gamma_i, \delta_i, \lambda_i, \omega_i$) of the matrix of θ . If the variables in the model (2) have a co-integration relationship, there must be an error-correction matter (ECM) (Engle and Granger, 1987; Pesaran and Shin, 1999), so we can judge the optimal lag term in the model by using one or more information standards (AIC, SC, HQ, etc.), and the values of *p* and *q*, and vice versa for models (3), (4), and (5). Therefore, we test the null hypothesis of whether there is a co-integration relationship between the sequence variables in the model, that is:

$$\text{Null hypothesis } H_0: \theta_i = 0$$

$$\text{Alternative hypothesis } H_1: \theta_i \neq 0, (i = 1, 2, 3, 4)$$

According to Pesaran et al. (2001), whether or not to reject the null hypothesis is determined by comparing the *F*-statistic of the correlation co-efficient in the *F*-test with the critical value of the ARDL co-integration co-efficient of the critical value of the maximum asymptotic spread of the *F*-statistic (Hao, 2021). However, as the selected sample size is rather small, we compare the value of the model *F*-statistic with the threshold value of the asymptotic distribution of the *F*-statistic suggested by Narayan (2005). (1) If the *F*-statistic of an estimated model is greater than the corresponding highest critical value in the critical values table, it is judged that a co-integration relationship exists between the variables and the null hypothesis is rejected. Conversely, when it is less than the lowest criterium in the criterium table, it is judged that no co-integration relationship exists between the variables. (2) If the *F*-statistic of the estimated model lies within the highest and lowest limits in the table of critical values, it must be assumed that the variable is an arbitrary mixture of *I* (0) and *I* (1).

According to the relevant definition, if the ARDL (*p*, *q*, *r*, *m*, *n*) co-integration model passes the criterium test of the *F*-statistic assay of the asymptotic dispersion, then a cointegrating or long-run link exists between the variables (Hao, 2021). Following Odhiambo (2009), the short-run economic activity parameters are derived by estimating an error-correction model with respect to the long-run estimation, and there is at least one causality amongst the variables in the direction determined by the *F*-statistic of the long-run estimation and the lag of the ECM. Therefore, we need to re-estimate the error-correction matter (ECM) in the model. According to Engle and Granger (1987) and Kalai and Zghidi (2019), an ARDL-VECM model is re-established for the variables in the model, and the combination of causality and ECM is used to further analyze the short-run dynamics between the variables in the model. That is, the short-run error-correction model is as follows:

$$\Delta IEG_t = \beta_1 + \sum_{i=1}^p a_{1i} \Delta IEG_{t-i} + \sum_{i=0}^q b_{1i} \Delta TRO_{t-i} + \sum_{i=0}^r c_{1i} \Delta FDI_{t-i} + \sum_{i=0}^m d_{1i} \Delta K_{t-i} + \sum_{i=0}^n e_{1i} \Delta X_{t-i} + \phi_1 ECM_{t-1} + \varepsilon_{1t} \tag{6}$$

$$\Delta TRO_t = \beta_2 + \sum_{i=1}^p a_{2i} \Delta TRO_{t-i} + \sum_{i=0}^q b_{2i} \Delta IEG_{t-i} + \sum_{i=0}^r c_{2i} \Delta FDI_{t-i} + \sum_{i=0}^m d_{2i} \Delta K_{t-i} + \sum_{i=0}^n e_{2i} \Delta X_{t-i} + \phi_2 ECM_{t-1} + \varepsilon_{2t} \tag{7}$$

$$\Delta FDI_t = \beta_3 + \sum_{i=1}^p a_{3i} \Delta FDI_{t-i} + \sum_{i=0}^q b_{3i} \Delta IEG_{t-i} + \sum_{i=0}^r c_{3i} \Delta TRO_{t-i} + \sum_{i=0}^m d_{3i} \Delta K_{t-i} + \sum_{i=0}^n e_{3i} \Delta X_{t-i} + \phi_3 ECM_{t-1} + \varepsilon_{3t} \tag{8}$$

$$\Delta K_t = \beta_4 + \sum_{i=1}^p a_{4i} \Delta K_{t-i} + \sum_{i=0}^q b_{4i} \Delta IEG_{t-i} + \sum_{i=0}^r c_{4i} \Delta TRO_{t-i} + \sum_{i=0}^m d_{4i} \Delta FDI_{t-i} + \sum_{i=0}^n e_{4i} \Delta X_{t-i} + \phi_4 ECM_{t-1} + \varepsilon_{4t} \tag{9}$$

where ECM denotes the correction term; ϕ_i denotes the rate at which the model adjusts or the ECM returns to the long-run equilibrium; The lag difference term coefficients (a_{ji} , b_{ji} , c_{ji} , d_{ji} , e_{ji}) reflect the momentum co-efficient of the model approaching balance in short run. According to ECM techniques, when co-efficient of the ECM's ϕ_i is significant or positive, it suggests the presence of long-run coarse gross causes. In contrast, if any variable's co-efficient is positive and significant in the ARDL-VECM model, it means that there is short-run gross cause.

Data sources. During recent years, ARDL model has been extensively acknowledged by scholars around the world in analyzing the link between trade openness (TRO), FDI and economic growth. However, very little research has been done on capital formation and industrial economy in China. At the same time, the majority of studies in literature have agreed that the ARDL model is mainly based on a combined framework of the econometric theoretical and statistical methods for explaining the dynamic relationships between variables. Therefore, in this study, to gain insight into the long-run and short-run dynamic link between China's trade openness, FDI, capital formation, and industrial economic growth, we select relevant data from the World Bank and the National Bureau of Statistics of China from 1990 to 2021 (see Table 1) and use the ARDL bounds test method to analyze it. Simultaneously, to mitigate the issue of ignoring variable deviations, additional factors of industrial economic growth, such as inflation, labor and technological innovation, were introduced into the model. In addition, taking into account the principles of comprehensiveness and usability attached to the data, all declared variables in the model were transformed into a double logarithmic format, and such transformation helped to obtain a relatively regular data distribution and to ameliorate the problem of heteroskedasticity, which made the estimated results meaningful and easy to interpret (see Table 2).

As mentioned above, the main purpose of this research is to examine the relation among TRO, FDI, capital formation (*K*) and industrial economic growth (IEG). Table 2 shows the results of the descriptor tests performed on the variables considered. The results show that the means of TRO, FDI, *K*, and IEG and the other selected variables (*L*, *TI*, and *INF*) are all positive. Specifically, *INF* had less variance than the other variables examined, but IEG had more variance than TRO and *K*, while *L* had the most variance among the selected variables. Moreover, the findings of the Jarque-Bera test indicate the chosen variables are usually spread, as the likelihood values of TRO, FDI, *K*, *L*, *TI*, and *INF* variables are each greater than the 5% significance level

Table 1 Variable description.

Variables	Description	Data source	Measure
<i>K</i>	Capital formation	World Bank	% of GDP
<i>L</i>	The volume of the total labor force	World Bank	% of total population
TRO	Trade openness	World Bank	% of GDP
<i>TI</i>	Technological innovation (patent application)	National Bureau of Statistics of China	Ten thousand
IEG	Industrial economic growth	World Bank	Industrial value added (% of GDP)
FDI	Foreign direct investment	World Bank	% of GDP
<i>INF</i>	Inflation rate: measured as percentage change in CPI	World Bank	Annual %

Table 2 Descriptive statistics of variables used.

Variables	Mean	Min.	Max.	Std. Dev.	Kurtosis	Skewnes	Jarque-Bera
K	3.699	3.514	3.843	0.105	1.845	-0.320	2.253
L	4.048	4.000	4.068	0.017	3.230	-0.876	4.029
TRO	3.711	3.189	4.166	0.252	2.410	0.129	0.534
TI	2.710	0.014	5.038	1.688	1.623	-0.075	2.477
IEG	3.788	3.633	3.862	0.068	2.496	-0.933	4.822 ^a
FDI	1.074	-0.034	1.822	0.527	2.529	-0.787	3.488
INF	0.975	-1.056	3.189	0.944	3.102	0.401	0.845

^aRepresent the values are significant at 10%.

Table 3 Extended dickey-fuller and phillips-perron tests.

Variables	ADF		PP		Int. order
	Level	1st difference	Level	1st difference	
IEG	-2.968	-3.066**	-2.623	-2.949*	I (1)
FDI	-2.968	-3.562**	-2.968	-3.352**	I (1)
TRO	-2.967	-3.633**	-2.967	-3.617**	I (1)
K	-2.968	-3.528**	-2.968	-3.474**	I (1)
L	-3.574	-3.795**	-3.574	-3.795**	I (1)
TI	-3.679	-5.155***	-3.679	-5.160***	I (1)
INF	-3.679	-5.348***	-3.679	-5.356***	I (1)

*Significant at the 10% level; **Significant at the 5% level; ***Significant at the 1% level.

Table 4 VAR lag order by the selection criteria.

Lag	LogL	LR	FPE	AIC	SIC	HQ
0	159.16	NA	6.54E-14	-10.494	-10.164	-10.390
1	376.87	315.33 ^a	6.40E-19 ^a	-22.130 ^a	-19.490 ^a	-21.303 ^a
2	418.45	40.128	2.09E-18	-21.617	-16.666	-20.067

^aindicates lag order selected by the criterion (significant at 5% level).

(Riti et al., 2017). However, IEG is found to be statistically significant at 10%, which means that China’s industrial economic growth is not normally distributed.

Empirical analysis and discussion of results

Unit root test. The objective of a unit root test is to examine the smoothness of the linear long-run association of the family members and to avoid spurious estimates due to pseudoregression. As can be seen in Table 3, the original series are non-stationary according to the ADF and PP stability tests, but are stationary series variables (IEG, TRO, FDI, K, L, TI, and INF) at the 10, 5, and 1% levels of significance according to the first-order difference. Thus, the selected series are all first order integrated I (1) (Engle and Granger, 1987). As the selected series are all first-difference smooth series, we should pay particular attention to the presence of co-integration across them. Hence, it is necessary to build a vector autoregressive model and use Akaike’s information criterion and Schwarz’s information criterion to identify the maximum lags of the model (Hao, 2021). Based on both criteria, the largest possible lag order of $p = 1$ (dependent variable) is selected in Table 4. In addition, when all selected variables are static at I (0) or I (1), the bounds test method is used, which is also one of the main benefits of using the ARDL estimate.

ARDL bounds test for co-integration. Typically, we use the ARDL bounds test to test whether or not long-term co-

integration exists between these variables (Hao, 2021). Firstly, the differenced estimation equations are identified and analyzed using the SIC selection criterion model, and the best lag of the ARDL model is identified. Secondly, a common F-test is carried out on every original variable (first-order lagged) and the critic value of the F-statistic of the ARDL conditional error-correction model based on the co-integration bounds test is used to finally determine the long-run correlation amongst the study variables included in the specified model (Pesaran et al., 2001; Narayan, 2005). Finally, according to the ARDL model co-integration estimation results (see Tables 5 and 6), it is found that the value of the F-statistic is greater than the upper limit at both the 5 and 1% levels of significance, indicating that there is long-run co-integration among IEG, TRO, FDI, K, L, TI, and INF and it is statistically significant at the 5% level of significance, which is consistent with the studies of Hao (2021) and Qamruzzaman and Wei (2018).

Long-run co-efficient estimated. Considering that the ARDL bounds test confirmed the persistence of long-run co-integration between IEG, FDI, TRO and K, it is necessary to use the ARDL (p, q, r, m, n) model to evaluate the long-run co-integration coefficients of each representative variable and to further analyse the impact of labor (L), technological innovation (TI) and inflation (INF) on IEG, TRO, FDI, and K (see Table 7). Table 7 shows the long-run of information criterion estimation results for different ARDL models (p, q, r, m, n). As can be seen from Table 7, FDI has a positive effect on IGE at the 1% significant level and vice versa, which supports the feedback hypothesis. This suggests that FDI influxes contribute to the level of industrialization, supply the resources and sophisticated technologies necessary for the development of China’s industrial economy, and perform an essential function in terms of economic growth, employment, income generation, and increased productivity, since when FDI increases by 1%, the industrial economy will increase by 0.071%, and conversely when the industrial economy increases by 0.071%, FDI will increase by 11.61%. This result is consistent with that of Liu (2002), Liu and Burrige et al. (2002), Mohammed and

Ruslee (2015) and Hung (2022). However, Rahman (2015) comes to the opposite conclusion and argues that FDI has a significantly negative impact on the development of industrialization, while Gu-Diby and Renard (2015) and Osuji (2015) suggest that FDI has no significant effect on the development of industrialization in African countries (Carkovic and Levine, 2002). The reason may be that the inflow of FDI leads to excessive repatriation of profits, which adversely affects the country's international balance of payments (Brecher and Diaz-Alejandro, 1977). In addition, Quazi (2004) and Vikas (2014) point out that under the conditions of an open economy, due to domestic capital flight (internal capital outflow), large inflows of FDI may have a negative impact on the domestic economy, leading to imbalances in the current account and foreign exchange accounts (Harrigan et al., 2002). On the other hand, industrial economic growth has a significant positive impact on TRO

and *K* at the 5% significance level, which shows that the development of industrialization in the context of economic globalization can promote China's trade exports and capital formation. While similar results are also found in the works of Keho (2017) and Rani and Kumar (2019), these results also support the works of Barro (1991) and Hye and Lau (2015), which reported a positive effect of the rate of *K* on the rate of IEG in a country. On the other hand, TRO exhibits a significant negative but diminishing effect on the rate of IEG. While this result is inconsistent with our theoretical hypothesis of a positive relationship between them, it supports the study by Malefane and Odhiambo (2021), which shows an insignificant or negative relationship.

In addition, in terms of control variables, *L* and INF both have a positive impact on IEG at the 1% significance level and have a negative impact on FDI at the 5% significance level, i.e., when labor and inflation increase by 1% each, the industrial economy will increase by 3.54% and 0.03%, respectively, while FDI decreases by 38.32% and 0.34%, respectively. This shows that inflation can, to a certain extent, stimulate the economy, increase market demand, and increase the production capacity of goods and services at lower labor costs, which will lead to higher production and thus increase industrial economic growth (Tariq et al., 2020). However, the increase in inflation will inevitably lead to an increase in production and labor costs, directly or indirectly reducing the net income of FDI. This result is consistent with the research results of Asiedu (2006), Sayek (2009), and Hailu (2010). However, it is not consistent with the results of Wafure and Nurudeen (2010) and Gharaibeh (2015), which illustrate that inflation is statistically insignificant but positively related to FDI. We also find that INF also has a positive impact on TRO, but the impact is relatively weak at the 10% significance level. This indicates that the increase in inflation has led to an increase in China's trade openness. This finding is consistent with that of Binici et al. (2012) and Zombe et al. (2017). Nevertheless, Romer (1993), Sachsida et al. (2003) and Gruben and McLeod (2004) come to the opposite conclusion. They suggest that there is a negative correlation between inflation and trade openness, and they also state that this relationship is not specific to a group of countries and a certain period (Sachsida et al., 2003). Therefore, with the increase in trade openness, a country's inflation rate has also declined. The study by Thomas (2012) also supports this

Table 5 Results of the ARDL Wald test (F-value) for long-run co-integration.

Dependent variable	<i>k</i>	F-statistic	Co-integration
IEG	6	7.295	Accepted
FDI	6	10.590	Accepted
TRO	6	6.445	Accepted
<i>K</i>	6	4.373	Accepted

IEG for industrial economic growth; FDI for foreign direct investment; TRO for trade openness, and *K* for capital formation.

Table 6 Boundary tests of criticism from Pesaran and Narayan.

Critical values	Pesaran et al. (2001)		Narayan (2005)	
	<i>I</i> (0)	<i>I</i> (1)	<i>I</i> (0)	<i>I</i> (1)
1%	2.88	3.99	3.71	5.33
5%	2.27	3.28	2.69	3.96
10%	1.99	2.94	2.25	3.39

Table 7 Long-run coefficients estimated using the ARDL approach.

	IEG _t Lag: SIC	FDI _t Lag: SIC	TRO _t Lag: SIC	<i>K</i> _t Lag: SIC
IEG _t		11.613*** [2.057]	2.207** [0.974]	2.324** [1.019]
TRO _t	-0.040 [0.049]	0.542 [0.553]		-2.224 [0.187]
FDI _t	0.071*** [0.015]		0.024 [0.077]	-0.196 [0.120]
<i>K</i> _t	-0.028 [0.073]	0.701 [0.837]	-0.122 [0.355]	
<i>L</i> _t	3.542*** [0.799]	-38.315** [12.592]	2.367 [0.698]	-5.007 [3.444]
TI _t	-0.005 [0.023]	0.162 [0.262]	0.044 [0.107]	0.226* [0.113]
INF _t	0.032*** [0.008]	-0.344** [0.114]	0.036* [0.021]	0.029 [0.018]
Constant	0.0002 [0.004] ARDL (1,2,0,1,2,1,2)	-0.027 [0.048] ARDL (1,0,2,1,2,1,2)	0.013 [0.022] ARDL (1,0,0,0,0,0,0)	-0.024 [0.021] ARDL (1,0,0,1,2,0,0)
Diagnostic test statistics (p-values)				
$\chi^2_{Normality}$	0.487 (0.784)	1.953 (0.377)	2.046 (0.360)	0.306 (0.858)
χ^2_{Arch}	0.259 (0.616)	0.228 (0.638)	0.048 (0.828)	0.289 (0.596)
χ^2_{Reset}	0.022 (0.885)	1.161 (0.304)	1.623 (0.217)	0.186 (0.672)
χ^2_{Serial}	0.698 (0.521)	0.848 (0.456)	6.201*** (0.009)	0.694 (0.515)

The columns in the table each present an estimation of a long-run model and the brackets indicate the average standard deviation. In brackets are the lag strengths selected based on SIC for each of the ARDL estimated models. We estimate using the common logarithm of these variables. Parentheses are probabilities in diagnostic test statistics. IEG for industrial economic growth, TRO for trade openness, FDI for foreign direct investment, GCF for gross capital formation, *L* for labor, *TI* for technological innovation and INF for inflation. *Significantly at 10% level; **Significantly at 5% level; ***Significantly at 1% level.

view, but points to the beneficial effect of openness on inflation, confirming the view that regional Caribbean countries are vulnerable to outside shocks. In addition, technological innovation has an expected positive impact on capital formation, but the impact is relatively weak at the 10% significance level. Therefore, in the long run, technological innovation has accelerated the formation of domestic capital in China to a certain extent, and achieved higher returns through industrial development investment in productive investment, resulting in long-run benefits (Qamruzzaman and Jianguo et al., 2020). This is in line with the results of Banerjee and Roy (2014). Unanimously, they argue that under the condition of technological progress, the contribution of domestic capital can increase exponentially with a certain effort, and they also think that capital formation and technological innovation are the key determinants of the actual economic output function.

ECM short-run dynamic ARDL estimation. Having examined the long-term links for the assigned models, it is relevant to examine the short-term dynamics of each agent according to the ECM-ARDL model (see Table 8). According to Hao (2021) and Hao et al. (2022), the error-correction term (ECM) then specifies the rate at which the model adjusts to long-run equilibrium and there is a period of shocks in the model. In addition, it is assumed that ECM is also negated and has a statistical relevance at the level of significance to account for the long-term correlation between the variables (Qamruzzaman and Wei, 2018; Fofana et al., 2019; Kalai and Zghidi, 2019). Table 8 shows that ECM(-1) for these assigned (IEG, FDI, TRO, and K) models are negative and found to be highly statistically insignificant at the 1% significance level, implying that the adjustment rate of each periodic shock to the model's long-run equilibrium is 82.7%, 102.7%, 101.4%, and 69%, respectively, which also indicates that the post-shock relationship process in the model has a good adjustment rate. Moreover, it also implies that once a shock has happened, the long-run is quickly adjusted back by 1.2 and 1.4 years for the IEG and K models, while the FDI and TRO models are adjusted to return to the current year's long-run equilibrium. Ahmed et al. (2013) pointed out that a very significant ECM is another indication of a time-stable link.

It can be seen from Table 8 that, TRO, FDI, and K have the expected positive impact on IEG, and vice versa. At the same time, TRO and K also have a positive impact on FDI, while FDI has a negative impact on capital formation, but the impact is relatively weak at the 10% significance level. In addition, we also find that FDI has a positive impact on TRO, and TRO has a negative

impact on K, but both are not statistically significant. This shows that under the background of economic globalization, China's industrial development has not only attracted a large inflow of FDI, but also improved China's domestic investment environment and capital market, directly or indirectly promoting an increase in international trade exports (Kalai and Zghidi, 2019). Meanwhile, a large inflow of FDI will inevitably lead to intensified competition in China's domestic investment market, which will adversely affect capital formation. For example, Eller et al. (2005) find that a large inflow of FDI will crowd out domestic capital and this finding is confirmed by the Firebaugh study (1992), who believes that in addition to crowding out domestic capital, FDI will also create a monopoly on the capital market (Rahman, 2015).

On the other hand, in terms of control variables, the short-run impact paths of L, TI, and INF on IEG, FDI, TRO, and K are almost the same as the long-run. According to Table 8, L, TI, and inflation have a significant negative impact on IEG and FDI, but inflation has a significant positive impact on TRO. In addition, we also find that labor has a significant negative impact on K, while technological innovation has a significant positive impact on it. This shows that inflation has caused people's expectations of currency depreciation, leading to an increase in industrial production and labor costs, and directly or indirectly adversely affecting FDI inflows. This is consistent with the studies of Faroh and Shen (2015), Xaypanya et al. (2015). However, Jaiblai and Shenai (2019) argue that they have no significant impact on FDI inflows. In this context, the inflow of FDI has decreased, leading to low technological innovation in high-tech fields and limited spillover effects, which in turn hinders the upgrading of the local industrial economy to the high end of the value chain and the transformation and development of the knowledge economy (Fu, 2008). On the contrary, the inflow of FDI is conducive to improving the domestic investment environment of a country and can play an important role in the formation of complementary capital (components) and is conducive to transforming technological opportunities into the overall dynamic capabilities required for innovative sales and market competitiveness. It will further enhance labor market competition, especially in terms of innovation, technology and talent.

Model robust test. To ensure the stability of the ARDL model established in this study, the statistical tests of recursive CUSUM and recursive CUSUMSQ for the specified model estimation parameters were used in this study (Hao, 2021). The results of the robustness tests (CUSUM and CUSUMSQ) for the ARDL model are shown in

Table 8 Error correction representation for the selected ARDL model.

	IEG_t Lag: SIC	FDI_t Lag: SIC	TRO_t Lag: SIC	K_t Lag: SIC
ΔIEG_{t-i}	0.173 [0.153]	11.927*** [2.186]	2.238** [0.989]	1.604*** [0.549]
ΔTRO_{t-i}	0.093*** [0.030]	1.338*** [0.432]	-1.014*** [0.159]	-0.155 [0.120]
ΔFDI_{t-i}	0.059*** [0.011]	-0.027 [0.126]	0.024 [0.078]	-0.058* [0.031]
ΔK_{t-i}	0.152*** [0.047]	2.438*** [0.637]	-0.124 [0.360]	0.310 [0.192]
ΔL_{t-i}	-3.062** [1.042]	-46.902*** [14.612]	2.400 [3.537]	-7.036** [3.337]
ΔTI_{t-i}	-0.040** [0.016]	-0.519** [0.187]	0.044 [0.109]	0.156** [0.059]
ΔINF_{t-i}	-0.009** [0.003]	-0.136** [0.048]	0.037* [0.021]	0.020 [0.012]
ECM(-1)	-0.827*** [0.086]	-1.027*** [0.089]	-1.014*** [0.122]	-0.690*** [0.098]
R ²	0.952	0.913	0.620	0.581
Adjusted R ²	0.891	0.805	0.493	0.334
Durbin-Watson	2.242	2.567	1.229	1.581
Log likelihood	108.238	33.649	49.911	60.768

The columns in the table represent the estimates of the short-run model and the brackets indicate the standard deviation. The natural logarithm of these variables is used in the estimation. IEG for industrial economic growth, TRO for trade openness, FDI for foreign direct investment, GCF for gross capital formation, L for labor, TI for technological innovation, and INF for inflation. **Significant at the 5% level; ***Significant at the 1% level.

Figs. 1 to 4. It can be seen that parametric constancy and model reliability are achieved when the levels of CUSUM and CUSUMSQ remain within the critical 5% range (shown by the red dashed line). According to the CUSUM and CUSUMSQ tests of the IEG and FDI models (see Figs. 1 and 2) the results reveal that the two statistics stay in the 5% significance range. However, the CUSUMSQ statistic in the

TRO and K models (see Figs. 3 and 4) exceeds the 5% significance range for the stability of the parameters. This suggests that there is instability and some lags in the coefficients, and the possible reason for this phenomenon is that the aftermath of the world economic crisis in 2008 led to a recession in China, which directly or indirectly affected trade exports and capital formation (i.e., the aftershocks of

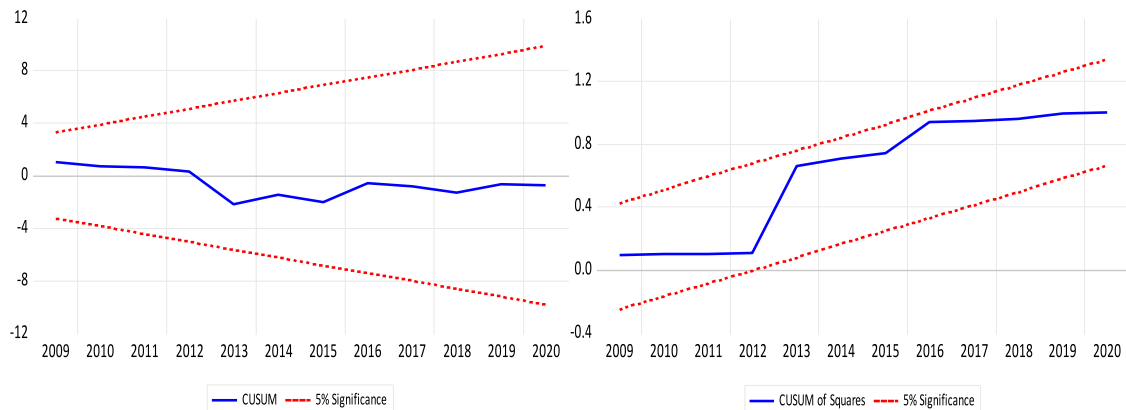


Fig. 1 Charts of CUSUM and CUSUMQ statistics for IEG. The CUSUM and CUSUMSQ test statistics remain within the 5% significant range (shown by the red dashed line), which indicates that the constructed IEG-ARDL model is robust and reliable.

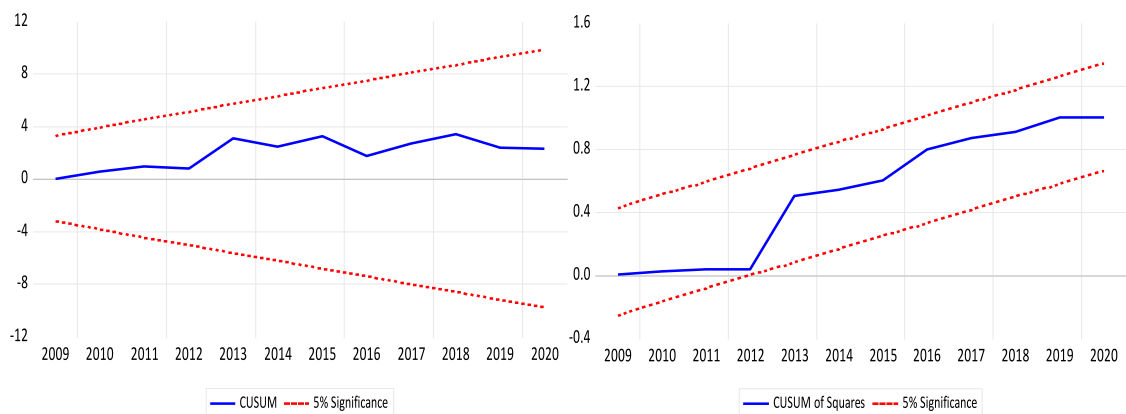


Fig. 2 Charts of CUSUM and CUSUMQ statistics for FDI. The CUSUM and CUSUMSQ test statistics remain within the 5% significant range (shown by the red dashed line), which indicates that the constructed FDI-ARDL model is robust and reliable.

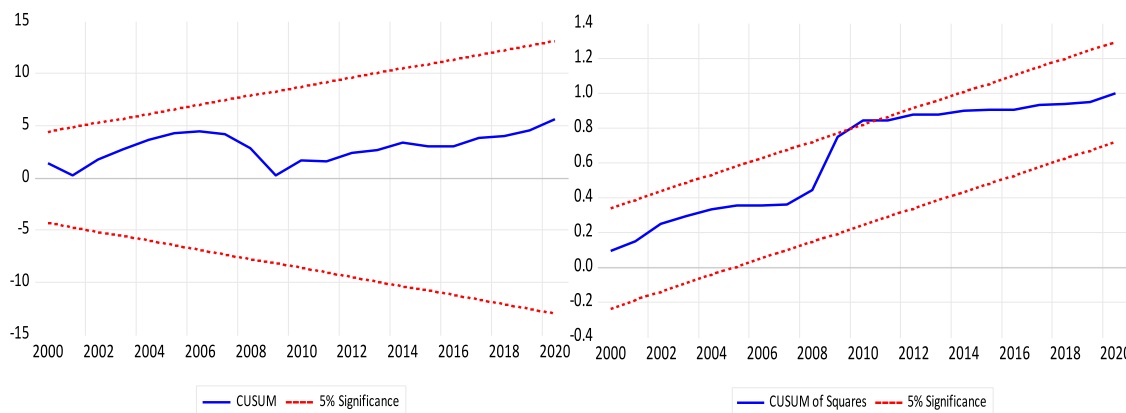


Fig. 3 Charts of CUSUM and CUSUMQ statistics for TRO. The CUSUM test statistic stays within the 5% significance range (shown by the red dashed line), but the CUSUMQ test statistic exceeds the 5% significance range for parameter stability, indicating that the estimated coefficients of the constructed TRO-ARDL model have instability and some lags, and the possible reason for this phenomenon is that the consequences of the 2008 world economic crisis led to the recession in China, which directly or indirectly affected the trade exports.

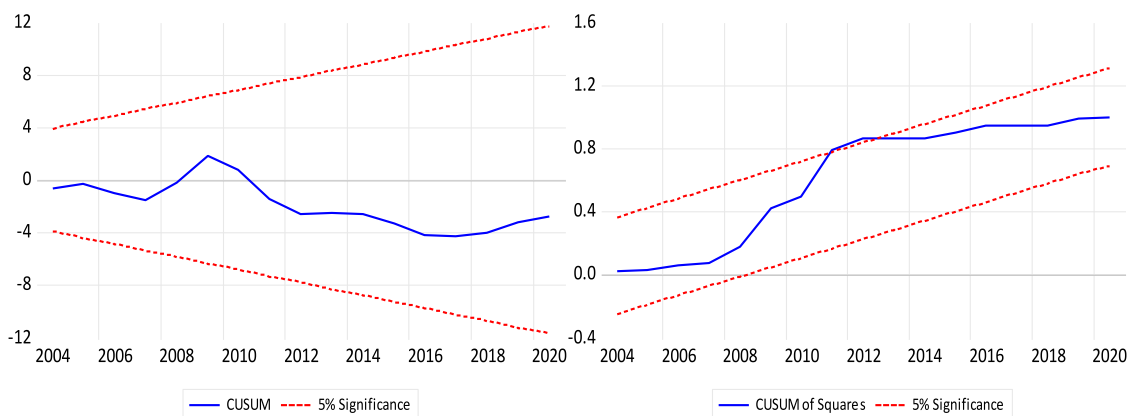


Fig. 4 Charts of CUSUM and CUSUMQ statistics for *K*. The CUSUM test statistic stays within the 5% significance range (shown by the red dashed line), but the CUSUMQ test statistic exceeds the 5% significance range for parameter stability, indicating that the estimated coefficients of the constructed *K*-ARDL model are unstable and have some lags, and the possible reason for this phenomenon is that the consequences of the 2008 world economic crisis led to a recession in China, which directly or indirectly affected capital formation.

the economic crisis) (Dixit, 2014; Hao and Cho, 2021). Overall, the model is effective and the study results are informative.

Conclusion and policy implications

We use annual data from 1990 to 2021 and apply the ARDL method to examine the long- and short-run dynamic relationships between China’s TRO, FDI, *K*, and IEG. The existing literature indicates that a large amount of research has been conducted to investigate the relationship between trade openness, FDI and economic growth. However, whether it is in developed or developing countries, some studies are based on trade openness and FDI inflow to drive domestic economic growth, and few studies examine the impact of trade openness and FDI on China’s industrial economic growth from the perspective of economy and market capital. Considering the existing research gaps, we incorporate TRO, FDI, *K*, and IEG into a multi-dimensional framework, and propose new insights for the development of China’s industrial economy.

Firstly, the ARDL-Bounds test has confirmed the existence of long-run co-integration in the four tested models (IEG, FDI, TRO, and *K*). Specifically, when the significance level is 5%, the *F*-statistics of each tested model is greater than the upper critical value. The research results provide conclusive evidence for a long-run link between TRO, FDI, *K*, and IEG, and this is consistent with the results of Blyde (2004), Mohammed and Ruslee (2015), Fofana et al. (2019), and Kalai and Zghidi (2019). Secondly, in order to capture long-run and short-run elasticity, the research results show that both long-run and short-run IEG has a positive impact on TRO, FDI and *K*, and it is also statistically significant, and vice versa. This is consistent with the results of Keho (2017), Fofana et al. (2019), and Rani and Kumar (2019). However, different from the short-run, in the long-run, TRO and *K* have a smaller negative impact on IEG, but it is not statistically significant (Malefane and Odhiambo, 2021). Finally, *K* and TRO also have a positive impact on FDI, while FDI has a negative impact on *K*, but the impact is negligible at the 10% significant level. On the contrary, they are not found to be statistically significant in the long run. In short, *K* based on economic and market capital will promote the long-term and continuous development of China’s industrial economy through high labor efficiency, financial sector facilitation, diversification of technological innovation, accumulation of capital, and long-term capital adequacy. In other words, a properly functioning capital market can expand the capacity of the country to use economic resources more effectively (Rani and Kumar, 2019).

Based on these results, relevant suggestions provided by this study for China’s future industrial development are as follows. Firstly, we should strengthen investment promotion, widely publicize China’s policy on the use of foreign investment, regulate and promote the development of development zones, continue to enhance foreign currency administration for FIEs, and simplify foreign currency capital settlement procedures for FIEs. As FDI has a beneficial effect on China’s national economic growth, it is necessary to further expand the introduction of FDI. Secondly, trade opening should be increased to attract FDI inflow through tax relief, policy funds to improve infrastructure construction and trade service mechanism to obtain more capital investment and technical support to provide all-round factor support for China’s industrial economic development to achieve the effect of economic aggregation. Thirdly, the current problem of “high in the east and low in the west” in China’s FDI and trade opening has led to a serious imbalance in the development of industrial economy in each region. Therefore, it is necessary to effectively connect the industrial resources in the central and western regions through measures such as industrial chain extension, enterprise cooperation and resource sharing to build an industrial circle with characteristic industrial advantages, so as to strengthen the introduction of FDI in the east and west regions, guide the east to implement industrial transfer to the west and promote the opening of the western region to the outside world. Finally, trade openness and FDI are also very important for increasing fixed capital formation. Therefore, the current Chinese government needs to continue to expand trade openness and speed up the approval of FDI projects to ensure the long-term inflow of FDI and foreign capital to form fixed production capital and boost industrial economic growth.

In addition, we used the ARDL-bounds approach to explore the factors influencing China’s industrial economic development, but there are still some relevant limitations. Additionally, in terms of data selection, we have not taken into account regional differences in China, and this may therefore lead to bias in the analysis. Of course, for the purposes of this study, this may also be a direction in which the model or analytical approach can be improved in the future.

Data availability

The data supporting this study’s findings are available on request from the corresponding author.

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Author contributions

Conceptualization: YH; methodology: YH; software: YH; validation: YH; formal analysis: YH; investigation: YH; data curation: YH; writing—original draft preparation: YH; writing—review and editing: YH; visualization: YH; supervision: YH; All authors have read and agreed to the published version of the manuscript.

Competing interests

The author declares no competing interests.

Ethical approval

This research was not required to receive any ethical approval because it did not involve human research participants and no primary data were collected. It uses data collected by statistical organizations such as the National Bureau of Statistics of China and the World Bank.

Informed consent

This article does not contain any studies with human participants performed by any of the author(s).

Additional information

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