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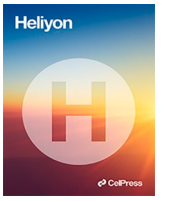

Research article

Economic openness, innovation and economic growth: Nonlinear relationships based on policy support

Ya Wen [a], Pingting Song [b], Chen Gao [c,*], Deyong Yang [a]

[a] School of Economics, Beijing Technology and Business University, Beijing, China
[b] Accounting School, Harbin University of Commerce, Harbin, China
[c] China Economics and Management Academy, Central University of Finance and Economics, Beijing, China

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ABSTRACT

Whether economic openness (EO) is conducive to promoting economic growth has become a common concern of many scholars and policymakers in China. Based on the panel sample data of 30 provinces in China from 2004 to 2018, this paper adopts an empirical model to test the relationship between EO and regional economic growth. The study identifies that expanding EO increases regional economic growth. After dealing with endogeneity issues, the results remain robust. The results of the mediation effect model show that technological innovation is an important channel for EO to accelerate economic growth. With the improvement of regional economic development, the benefits of EO will increase. However, its positive effect has slowed down in regions with very high levels of economic development. The outbreak of the financial crisis has weakened the driving force of EO on economic growth, while the Belt and Road Initiative has strengthened the positive impact of EO. In addition, when introducing the threshold variable of policy support to examine the nonlinear relationship between variables, it is found that deepening the policy intensity will significantly improve economic growth due to the benefits of EO.

1. Introduction

Many scholars focus on the growth effect of economic openness (EO), and China is the most typical example in this research field [1-3]. Since the implementation of the policy of reform and EO, China has made remarkable achievements in various aspects and has become the second largest economy in the world. The prosperity of China's economy is inseparable from "reform" and "EO". Especially after China acceded to the WTO, EO played a more critical role in economic development [4].

China has made new steps in reform and made new accomplishments in economic development. It is widely acknowledged that a country's economy can be linked to the world economy by EO. China aims for a higher level of EO. Despite its late economic reform and EO policy, China has achieved fruitful results in attracting foreign investment and conducting international business with other countries. In 2020, China's outbound foreign direct investment (OFDI) reached $153.71 billion, ranking first in the world for the first time; the outbound investment reached $144.37 billion, a year-on-year increase of 4.5%; trade openness increased to 31.65%. In addition, we also draw a line graph of the ratio of China's GDP growth rate to the world's (see Fig. 1). Overall, China's GDP growth rate is about three times that of the world. The outliers in 2008 and 2009 were due to the financial turmoil. On the one hand, China can take

* Corresponding author.
E-mail address: 2019110187@email.cufe.edu.cn (C. Gao).

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advantage of its trade surplus to drive economic growth and optimize the balance of payments by raising the EO level [5]. On the other hand, under the dual pressure of COVID-19 and trade friction between China and the United States, China has put forward a "double-cycle" model to integrate deeply into the global economy. Therefore, it is of great significance to further explore the impact of EO on economic growth, establish an open economic system, and facilitate high-quality economic development.

Scholars generally believe that opening to the outside world stimulates economic development. Theoretically, the neoclassical theory proposes that EO contributes to improving resource allocation, which in turn is helpful to economic development [6,7]. The new growth theory suggests that EO can drive economic development by accelerating technological progress and increasing productivity [8,9]. In terms of empirical evidence, some studies have found that China's economic development benefits from opening to the outside world. Although most scholars have proved that exports are an important engine driving China's economic growth [10], imports and FDI favor economic transformation. The reason is that import and FDI encourage technological progress in the same industry and enhance economic performance [11]. Besides, there is also empirical evidence that EO and economic growth are not linear. Osei et al. argued an inverted U-shaped relationship exists between EO and economic growth in low- and middle-income African countries [12]. Iyidoğan et al. regarded financial deepening as a threshold variable, denoting that the economy of Central and Eastern Europe will only move from opening to development after a certain threshold is exceeded [13]. Using China as a research sample, Kong et al. found that China's opening and growth were N-type but did not further clarify the reasons [14].

Trade and advanced technology have played a vital role in China's economic growth since the early 21st century. Exports stimulate demand for economic output and create new jobs in the country [15]. In an open economy, economic growth is driven by technology and knowledge transferred through international trade [16]. As a representative of the New Growth Theory, Romer proposed the technological spillover effect of international trade [8]. It has a promoting effect on the technological progress of the country, which in turn stimulates economic growth. This view has been supported by the research of most scholars [17,18]. Applying generalized estimation of moments, Sultanuzzaman et al. examined the impact of exports and technology on economic performance in emerging Asian economies from 2000 to 2016 [19]. They found that exports and technology have positive and significant influence on economic growth, and the results are robust using alternative dynamic panel models.

Foreign direct investment and domestic investment have consistent effects on economic growth. In endogenous growth models, FDI is often considered to be more productive than domestic investment, and it can introduce new technologies into domestic production functions [20]. Tuan et al. estimated the effect of FDI on regional economic development by using panel data of cities in the Pearl River Delta and Yangtze River Delta, two globalized economies since China's reform and opening up [21]. Their results showed that FDI not only directly affects output growth and productivity progress, but also indirectly increases economic growth by raising total factor productivity. Tshepo employed Johansen cointegration test and Granger causality test to examine the role of foreign direct investment on economic growth and employment in South Africa during the period 1990–2013, and confirmed that FDI was seen as a mechanism to promote economic growth and employment in South Africa [22]. Owusu adopted a multivariate Granger causality model under the ARDL boundary test framework to explore the relationship between foreign direct investment and economic growth in Namibia, and the results showed that there was a strong two-way causality between the two [23]. Besides, some scholars have found that foreign direct investment has no significant impact on a country's economic growth, and even inhibits economic growth [24,25].

Innovation is an important accelerator to push the economy from opening to growth. Branstetter found that FDI had a technology spillover effect on both investors and invested countries [26]. The host country achieves technology accumulation through imitation, which then enhances the independent innovation capacity through secondary absorption to promote economic growth [27,28]. Some scholars used China's provincial data to clarify that FDI has technology spillover effects [29,30]. After absorbing foreign technologies, China has improved its independent innovation ability [31,32], and realized an innovation-driven development strategy [33]. For investors, OFDI will also improve sustainable innovation. The main reason is that China has a technological reverse spillover effect in the process of innovation is an important accelerator to push the economy from opening to growth. And enterprises have the incentive to continue innovation to gain international competitiveness [34].

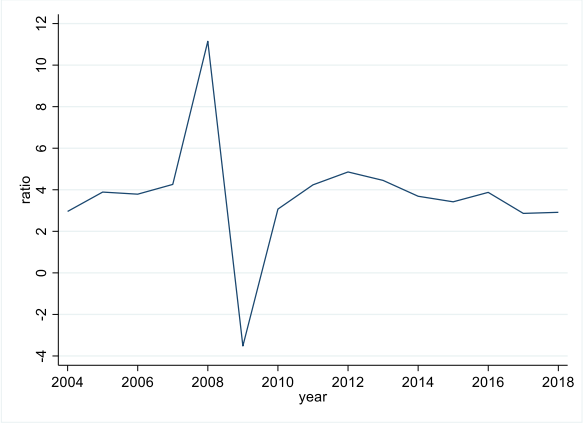

Fig. 1. Ratio of China's GDP growth rate to the World's.

Innovation is the engine of development. R&D investment and innovation performance provide great potential for the economic development of enterprises and countries. Whether the technologies are imported or developed independently, enterprises can increase their competitiveness and market shares by applying patented technologies [35]. For countries, the economic effect of innovation requires the joint role of infrastructure, policies, and incentive systems [36]. Generally speaking, developing countries rely on technology introduction to increase productivity, while developed countries increase productivity through independent innovation [37]. Innovation can significantly improve employment, and high-tech industries can absorb more jobs than low-tech industries [38]. For example, Salam et al. demonstrated that digital technology has enhanced human capital and accelerated economic growth. But technological innovation and economic growth are not entirely linear [39]. He pointed out an inverse u-shaped relationship between technological innovation and economic growth in the economic cycle, confirming that when the economy introduces a quadratic term for innovation, the economic growth rate rises [40]. Law et al. took Malaysia as the subject [41]. They denoted that the quality of technological innovation contributes to the growth of the national economy, and technological exchange is an important factor in promoting economic growth. Therefore, it is necessary to build a sound institutional framework, accumulate the quality of human capital, build extensive network connections, and speed up the marketization process of scientific and technological innovation.

Achieving sustainable development within the institutional framework requires macro-policy adjustments [42,43]. Uncertain economic policies can worsen existing and future investment environments, seriously threatening stable economic growth [44,45]. But flexible economic policies under the strategic stability goal will boost economic growth. China's policies have kept pace with the times and promoted rapid economic development [46]. Xu verified that the global financial crisis in 2008 brought disaster to the world economy [47]. However, China made timely policy adjustments in domestic and foreign situations. The policy ensured the primary stability of China's economy and accelerated the pace of economic recovery. In addition, the Belt and Road policy has strengthened infrastructure construction and connectivity among countries along the routes and strengthened China's strategic trade and economic position [48]. The policy has driven the economic growth of countries along the routes [49,50].

This paper uses China's 2004–2018 provincial panel data for research and highlights the marginal contributions of: First, from the research perspective, we deeply study the economic effect of opening to the outside world. This paper enriches the literature on the economic growth effect under the background of openness. Second, based on the relevant theory of economic growth, the influence mechanism of EO on economic growth is systematically derived. It provides a valuable reference for comprehensively improving the level of EO to the outside world. Third, in terms of the research methods, we employ the semi-parametric estimation method and the generalized additive model (GAM model) to fit the relationship between EO and economic development. Then, we use benchmark regression to estimate. Fourth, we adopt the robustness test to solve the endogenous problems. The opening effect of different economic development areas was examined by quantile test to explore the difference in opening effect in different regions. We investigate the differences in openness's economic effects under the financial crisis and the Belt and Road initiative. Finally, considering that policy support is different strength among regions, it may affect the EO of economic growth. Accordingly, this paper adopts the threshold effect model to deeply study the non-linear relationship between EO, policy support, and economic growth. It has an extraordinary enlightenment effect on improving the efficiency and competitiveness of EO.

The rest of this paper is organized as follows: Section 2 summarizes the review of the existing literature. Section 3 presents the data and methods used in the study. Section 4 analyzes the empirical results and discussion. Finally, Section 5 contains conclusions and policy recommendations.

2. Methodology

2.1. Preliminary investigation

The existing papers did not set up the specific function form of EO on economic growth, mainly staying at the level of implicit

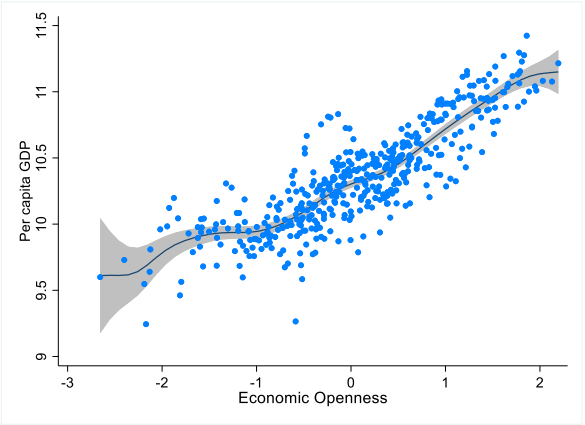

Fig. 2. Gaussian kernel regression distribution of EO to per capita GDP.

function. In order to preliminarily verify the impact of EO on regional economic growth, this paper uses the generalized additive model (GAM model) to fit the relationship between EO and economic development. Learning from Parteka [51], the GAM estimation equation for EO and Economic Development (Growth) is as follows:

$$Growth_{it} = \alpha x_i + g(EO_{it}) + \varepsilon_{it} \tag{1}$$

In equation (1), i and t indicate the province and the year, respectively, and $Growth_{it}$ denotes the level of economic development. The parameter part αx_i is a linear function, and ε_{it} is a random perturbation term with the mean independent of the x_i. Assuming that g (EO_{it}) is an unknown function of the external opening, its kernel density follows a Gaussian kernel function, and the kernel density estimator is as follows：

$$\widehat{f}(x_i, x_0, h) = \frac{1}{nh}\sum\nolimits_{i-1}^{n} K\left(\frac{x_i - x_0}{h}\right) \tag{2}$$

In equation (2), $\widehat{f}(x_i, x_0, h)$ represents the probability density of the sample x_0, and the function $K(\cdot)$ is the weight function. h is the "smooth parameter," known as the "bandwidth," which defines the size in the domain near x_0. The larger the bandwidth h, the smoother the estimated density function is. Using panel data from 30 provinces and autonomous regions of China from 2004 to 2018, this paper presents a gauss nuclear regression graph of the per capita GDP of China's opening to the outside world, as shown in Fig. 2. The chart mainly reflects the positive effect of EO on economic development. Economic development shows an upward trend with the deepening of EO to the outside world. At the same time, the slope of the curve has changed, indicating that the effect of EO on economic growth is greatly different at different stages of economic development.

2.2. Model setting

Based on the analysis of the above theoretical mechanism and the observation of the semiparametric estimation test, this paper constructs a panel data model to test the promotion effect of EO on economic growth, which is as follows:

$$GGDP_{it} = \alpha_0 + \alpha_1 EO_{it} + \sum\nolimits_{j=2}^{J} \alpha_j C_{it}^{j} + \omega_i + \omega_t + \varepsilon_{it} \tag{3}$$

Economic growth ($GGDP_{it}$) is the explained variable of this paper, and the level of EO (EO_{it}) refers to the core explanatory variable. The control variable C_{it}^{j} includes industrial structure (IS), educational level (EDU), social investment in fixed assets (IFA), financial level (FD), urbanization rate (URB), jobless rate (UNR) and fiscal support (FS). ω_i and ω_t represent regional fixed effect and time fixed effect, respectively; ε_{it} is a random disturbance term.

Table 1 provides the different statistics of all variables which describe our sample. It is reasonable for us to select these variables for regression.

Meanwhile, we employed the Variance Inflation Factor (VIF) to test for multicollinearity across all variables (See Table 2). The results of test showed no multicollinearity among all explanatory variables.

2.3. Measurement of economic openness

There are four main ways of economic openness (EO): foreign direct investment, foreign direct investment, export and import. The existing literature have only studied one way of EO impact on regional economic growth, but did not consider the comprehensive economic effects of these four approaches. This paper first standardizes the OFDI, FDI, export and import data of each province, and then the processed data is analyzed by dimension reduction to generate a comprehensive index of economic openness. The results of the factor analysis are shown in Table 3. Among the four factors of OFDI, FDI, export and import, only the first characteristic factor value (Eigenvalue) is 3.51552, greater than 1. The contribution rate of its variance (Proportion) is 0.8789, i.e. about 88% of the information volume explains the raw data. The chi-square value of the LR test shows that, chi2 (6) = 2282.26, and the P-value (Prob > chi2) is 0.0000. It is reasonable to choose this factor as the comprehensive evaluation index of economic openness.

By rotating the load matrix, we obtain the corresponding eigenvector, and the main factor expression can be written as follows:

Table 1
Descriptive statistics of the variables.

Variables	Number of samples	Average	Standard deviation	Min	Max
GGDP	450	9.957	3.207	−2.300	23.600
EO	450	0.077	0.915	−2.655	2.195
IS	450	0.888	0.059	0.631	0.997
EDU	450	8.750	1.025	6.378	12.770
IFA	450	0.683	0.247	0.234	1.480
FD	450	0.053	0.030	0.006	0.177
FS	450	0.215	0.096	0.079	0.627
URB	450	0.530	0.141	0.263	0.896
UNR	450	3.517	0.683	1.210	6.500

Table 2
Results of the VIF test.

Variable	VIF	1/VIF
URB	7.97	0.125474
EDU	4.97	0.201207
FS	3.70	0.270206
FD	3.65	0.273988
EO	3.60	0.277519
IS	2.58	0.387692
IFA	2.11	0.473529
UNR	1.49	0.671426
Mean VIF	3.76	

Table 3
Factor analysis of the basic information.

Factor	Eigenvalue	Equation contribution rate	Cumulative contribution rate
Factor1	3.51552	0.8789	0.8789
Factor2	0.32038	0.0801	0.9590
Factor3	0.10002	0.0250	0.9840
Factor4	0.06408	0.0160	1.0000

Note: LR test: chi2 (6) = 2282.26 Prob > chi2 = 0.0000.

$$EO = 0.8655 * OFDI + 0.9614 * FDI + 0.9507 * EXP + 0.9686 * IMP \quad (4)$$

EO represents a comprehensive indicator of economic openness. To verify the effect of the principal component analysis above, we need the KMO test and the SMC test. The KMO test is used to measure the strength of the correlation between the variables. By comparing the correlation coefficient and the partial correlation coefficient, the KMO value is between 0 and 1. The larger the KMO value, the more the principal component analysis can play a good data reduction effect. In general, KMO values are greater than 0.7. While the SMC test is the square of the complex correlation coefficient of a variable with all the other variables, namely, the dependent index of the complex regression equation. The higher the SMC values indicate that the stronger the linear relationship of the variables, and the more reasonable the PCA is. The results of Table 4 shows that all variables meet the requirements and obtain comprehensive indicators of economic openness.

2.4. Data source and variable definition

To ensure the balance of panel data, we select 30 provinces from 2004 to 2018. Referring to the methods of Cetin and Dogan [52] and Ecevit et al. [53], we selected a series of control variables to add to the empirical model. The definitions of variables, specific measures, and descriptive statistics involved in the full text are shown in Table 5. All data mainly from the Provincial Statistical Yearbook, China Statistical Yearbook, China Science and Technology Statistical Bulletin, Statistical Bulletin of China's Outward Foreign Direct Investment, UNESCO Database, UNCTAD Database, and individual missing data is complemented using the Wind database.

3. Results and discussion

3.1. Regression results

Before empirical testing, we should choose an estimation method for the balanced panel data. The Hausman test shows that it is suitable to test the effect of EO on regional economic growth in the benchmark regression.

Table 6 shows benchmark and mediation effect estimation results. In column (1), it reports the estimates of Equation (3), showing the impact of the comprehensive indicators of EO on economic growth. In order to avoid the change in economic growth with the region and time, this paper also controls the regional effect and the time effect to make the results more accurate. The results show that

Table 4
The KMO and SMC values of the variables.

Variable	KMO	SMC
OFDI	0.9607	0.6093
FDI	0.8424	0.8843
EXP	0.8711	0.8596
IMP	0.7975	0.9064
Total	0.8580	–

Table 5
Definition of variables.

Variable symbol	Variable name	Measurement method	Source
GGDP	Economic growth	Real growth rate of per capita GDP	China Statistical Yearbook
EO	Economic openness	It is synthesized by the principal component analysis method of OFDI, FDI, export and import	Principal Component Analysis
OFDI	Outward foreign direct investment	Log processing of OFDI data	Statistical Bulletin of China's Outward Foreign Direct Investment
FDI	Foreign direct investment	Log processing of FDI data	Provincial Statistical Yearbook
TRA	Total foreign trade	Log processing of trade volume	UNCTAD Database
EXP	Export level	Log processing of export volume	UNCTAD Database
IMP	Import level	Log processing of import volume	UNCTAD Database
IS	Industrial structure	(Added value of secondary industry + added value of tertiary industry)/GDP	China Statistical Yearbook
EDU	Educational level	(Primary school * 6 + junior middle school * 9 + senior high school * 12 + junior college or above * 16)/population over 6 years old	UNESCO Database
IFA	Social investment in fixed assets	Total social fixed assets investment/GDP	China Statistical Yearbook
FD	Financial level	Industry added value (finance)/GDP	China Statistical Yearbook
URB	Urbanization rate	Urban permanent population/area total permanent population	China Statistical Yearbook
UNR	Jobless rate	Registered urban unemployment rate	China Statistical Yearbook
TEC	Technological innovation	It is synthesized by three subvariable principal component analysis methods of patent application acceptance, technology market turnover and R&D investment level	China Science and Technology Statistical Bulletin
PAT	Acceptance of patent applications	Number of patent applications accepted (pieces)/total population (ten thousand people)	China Science and Technology Statistical Bulletin
TMT	Technology market turnover	Technology market turnover/GDP	China Science and Technology Statistical Bulletin
RD	R&D investment level	R&D investment/GDP	China Statistical Yearbook
FS	Fiscal support	General public budget expenditure/GDP	China Statistical Yearbook
HR	Talent support	Local financial expenditure on education/GDP	China Statistical Yearbook

the impact of EO on regional economic growth is significantly positive, conveying that expanding EO can promote local economic development. Cetin [54] and Nguyen [55] also supported the results.

This paper further constructs a gradual regression model to examine the internal effect of regional EO on economic growth. Mediated effects were employed in order to examine their potential vertical conduction mechanism. The inspection process is as follows: if there is a vertical transmission process of " EO-innovation-economic growth". We set the mediation effect model as follows:

$$\mathrm{TEC}_{it} = \theta_0 + \theta_1 EO_{it} + \sum_{j=2}^{J} \theta_j C_{it}^{j} + \omega_i + \omega_t + \varepsilon_{it} \tag{5}$$

$$GGDP_{it} = \eta_0 + \eta_1 EO_{it} + \eta_2 \mathrm{TEC}_{it} + \sum_{j=3}^{J} \alpha_j C_{it}^{j} + \omega_i + \omega_t + \varepsilon_{it} \tag{6}$$

TEC_{it} indicates the comprehensive index of innovation. We use the principal component analysis method to reduce the dimension of the patent application acceptance, the technology market turnover, and the level of R&D investment. The control variable (C_{it}^{j}) remain unchanged as above, ω_i and ω_t refer to the fixed effects of province and time. Columns (2, 3) report the estimated results of Equations (5) and (6), respectively.

In column (2) of Table 6, the estimated coefficient of the regional innovation capacity is significantly positive, demonstrating that enterprises' participation in the EO can considerably improve the local innovation level. Li and Tian also found that foreign trade

Table 6
Benchmarking and mediation effect regression results.

Variables	FE			2SLS		
	GGDP	TEC	GGDP	GGDP	TEC	GGDP
	(1)	(2)	(3)	(4)	(5)	(6)
EO	4.198*** (0.636)	0.257*** (0.0959)	3.867*** (0.630)	4.966*** (1.016)	0.265* (0.144)	4.638*** (0.992)
TEC			1.289*** (0.326)			1.236*** (0.366)
Control variables	YES	YES	YES	YES	YES	YES
Province effect	YES	YES	YES	YES	YES	YES
Time effect	YES	YES	YES	YES	YES	YES
R2	0.755	0.710	0.764	0.797	0.953	0.805
N	450	450	450	450	450	450

Note: The values within the parentheses are the standard deviation; *, **, and *** represent the significance levels at 10%, 5%, and 1%, respectively.

transfers products and services at international intervals and provides important conditions for the innovation and diffusion of high and new technologies [56]. Column (3) shows the estimation results of explained variables on the explanatory and intermediary variables: the regional economic growth on the EO and scientific and technological innovation. The estimated coefficients of both EO and innovation are significantly positive. It preliminarily shows the existence of an intermediary effect; that is, opening to the outside world stimulates regional economic growth via improving scientific and technological innovation.

3.2. The endogeneity problem

Opening up to the outside world will have a specific sustained impact on the economic growth rate; the previous EO will affect the current economic growth. We use the Hausman to test the endogeneity. The results showed that the null hypothesis was rejected at the 1% significance level, considering EO as an endogenous variable. Columns (4–6) of Table 6 report the estimation of Equations (4)–(6) using the two-stage least squares (2SLS) method. Applying the instrumental variable method, the estimated coefficient for the EO increases from 4.198 to 4.966 compared to the above estimates for the fixed effects model. We can conclude that ignoring endogeneity significantly deviates the least-squares estimation results; that is, it significantly reduces the role of EO on regional economic growth. Hence it is necessary to use the instrumental variable method to estimate the robustness. Compared with the regression results of column (1) and column (4), the estimated value of the open estimation system decreased after the addition of the intermediary variable. The standard error of the estimation coefficient is also slightly reduced. Therefore, it can be considered that the fit degree of the regression equation is better after introducing the intermediary effect, which means that scientific and technological innovation is the core channel of EO to the outside world to accelerate regional economic development.

3.3. Further discussion

3.3.1. Quantile regression

In the above regression model, the paper highlights the influence of EO on regional economic growth. The dependent variable shall be subject to normal distribution before regression analysis. Both the collinearity problem and the heteroscedasticity problem may lead to deviation in the regression results. We cannot understand the change process of the influence trend of independent variables on dependent variables only through regression analysis, while quantile regression can solve this problem well. In order to explore the impact of EO on different levels of economic development areas, this paper needs the quantile regression test, and Columns (1–5) of Table 7 are the results. We focus on the coefficient size and significance of the estimated EO at different quantiles. First, the EO coefficients increase successively at the 10%, 25%, 50%, 75%, and 90% quantiles. With the rise of the regional economic development level, EO can form competitive advantages and encourage more innovation activities to promote rapid economic growth in the area. The possible reason is that regions with high economic growth have productivity and science and technology advantages. EO will further stimulate their advantages, increase the market shares of domestic enterprises, and enhance their innovation capabilities [57]. Therefore, the level of regional economic development will affect the utility of EO to regional economic growth. However, the opening-up estimation coefficient is insignificant on the 10% quantile. So EO has no economic growth effect on the provinces with a low level of economic development. It also reflects a series of problems in Western China, such as a low level of economic development, a small scale of foreign trade, and low utilization of foreign capital. These problems limit the further development of EO. Although the implementation of the western development strategy has greatly promoted its economic development and foreign trade, there is still a significant gap compared with the central and eastern regions [58].

Table 7
The regression results of further discusses.

Variables	The quantile test					The financial crisis and the impact of the "Belt and Road"		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	10%	25%	50%	75%	90%			
EO	0.883	1.603*	2.350***	3.531***	3.856***	5.167***	4.882***	5.229***
	(1.090)	(0.877)	(0.795)	(0.555)	(1.116)	(1.012)	(0.996)	(0.982)
EO × crisis						−0.602**		−1.072***
						(0.278)		(0.249)s
EO × road							1.600***	1.826***
							(0.237)	(0.220)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES
Province effect	YES	YES	YES	YES	YES	YES	YES	YES
Time effect	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.6053	0.5911	0.6165	0.6438	0.6291	0.800	0.819	0.826
N	450	450	450	450	450	450	450	450

3.3.2. The impact of the "financial crisis" and the "Belt and Road"

This paper will verify the impact of the global financial 2008 crisis and the 2013 "Belt and Road" Initiative on an open economy. We introduce the cross term of 0–1 dummy variable corresponding to these two exogenous variables, which are estimated using the following models:

$$GGDP_{it} = \beta_0 + \beta_1 \mathrm{EO}_{it} + \beta_2 \mathrm{crisis}_{it} + \beta_3 \mathrm{EO}\times\mathrm{crisis}_{it} + \sum_{j=4}^{J} \beta_j C_{it}^{j} + \omega_i + \omega_t + \varepsilon_{it} \quad (7)$$

$$GGDP_{it} = \gamma_0 + \gamma_1 \mathrm{EO}_{it} + \gamma_2 \mathrm{road}_{it} + \gamma_3 \mathrm{EO}\times\mathrm{road}_{it} + \sum_{j=4}^{J} \gamma_j C_{it}^{j} + \omega_i + \omega_t + \varepsilon_{it} \quad (8)$$

where crisis_{it} represents the dummy variable of the financial crisis, and it means the value is 1 when $t \geq 2008$, otherwise the value is 0. If β_3 is negative, it indicates that the 2008 financial crisis weakened the role of EO in encouraging regional economic growth, while it strengthened its positive impact. Similarly, road_{it} refers to the dummy variable of the Belt and Road Initiative. When $t \geq 2013$, the Belt and Road Initiative (road_{it}) is valued at 1; otherwise, road_{it} is valued at 0. If the γ_3 is positive, it can be found that the Belt and Road Initiative in 2013 has strengthened the impact of EO in improving regional economic growth. On the contrary, if the γ_3 is negative, it weakens its positive effect. The control variable (C_{it}^{j}) is the same as above, and indicates the fixed effects of province and time, respectively.

In Table 7, columns (6–7) report the estimated results of Equations (7) and (8), respectively, and column (8) simultaneously introduces two interaction terms into the model for robustness testing. The results in columns (6–8) convey that the regression coefficients for the open world and financial risk interaction terms are negative and pass the 1% significance test. It states that the 2008 global financial crisis weakened the increasing effect of EO on regional economic growth and also supports the view of Shi [59]. It is worth noting that the regression coefficient of EO to economic growth is still substantially positive, which fully verifies that under the impact of the world financial crisis. Nevertheless, the impact of EO on economic growth has been weakened, and it has not changed its positive effect. The results in columns (7–8) illustrate that the regression coefficient of the interaction terms of EO and the Belt and Road Initiative is considered positive. It proves that since China proposed the "Belt and Road" Initiative in 2013, it has substantially strengthened the economic role of EO. Especially in 2020, multinational corporations have suffered from the COVID-19 pandemic. The "Belt and Road" Initiative has accelerated the pace of "going out" of enterprises and achieved the goal of high-quality development of foreign trade [60].

4. The threshold effect test of EO and economic growth

China's policy and the system are important in motivating enterprises' participation in international trade [61]. The Chinese economy is in a critical transition period from an extensive to an intensive development model. In this process, the government has adopted relevant policies to support economic growth mode transformation [62]. Strict government control can accumulate human capital and upgrade the industrial structure to optimize productivity and regional economic development. Data from the China Market Index Report also indicates that the government and market relationship is significantly different in provinces and autonomous regions. Based on this, we will further examine whether policy support will lead to a nonlinear relationship in the influence of EO on regional economic growth (see Fig. 2). Therefore, this paper introduces the threshold variable based on the benchmark regression model for nonlinear regression and sets the following single threshold model:

$$GGDP_{it} = k_0 + k_1 \mathrm{EO}_{it} \times I(FP_{it} \leq \gamma) + k_2 \mathrm{EO}_{it} \times I(FP_{it} > \gamma) \sum_{j=3}^{J} \alpha_j C_{it}^{j} + \omega_i + \omega_t + \varepsilon_{it} \quad (9)$$

where the upper-medium policy support (FP_{it}) is the threshold variable, including fiscal support (FP_{it}), talent support (HR_{it}), and R&D support ($_{RDit}$). $_{\gamma}$ is the threshold value to be estimated, $I(\bullet)$ refers to the schematic function. If the conditions in parentheses are true, I takes the value of 1; otherwise, the value is 0. k_1 and k_2 are the influence coefficients of the threshold variable when the effect of EO on regional economic growth is at $_{FP_{it}\leq\gamma}$ or $_{FP_{it}>\gamma}$.

In this paper, we select the degree of financial, talent, and research and development support as the threshold variables to analyze whether there is a threshold effect between EO and growth. First, the number of thresholds needs to be determined, and the results are shown in Table 8. We can find that financial, talent, and R&D support all passed the 10% significance test. However, none pass the significance test of the double-threshold effect. Therefore, these three threshold variables only have a single threshold value, which is suitable for adopting a single threshold model.

This paper uses a fixed-effect model to test whether the policy support influences the opening-driven regional economic growth.

Table 8
Threshold value test for the relationship between policy support and EO.

The threshold type	A single threshold		Double threshold	
	Threshold value	F statistics	Threshold value	F statistics
FS	0.2073	72.05*** [0.000]	0.2073 0.2681	20.14 [0.1880]
HR	0.0251	23.93* [0.084]	0.0251 0.0189	14.46 [0.2110]
RD	0.0337	39.20** [0.031]	0.0337 0.0218	11.56 [0.4500]

The estimated results of equation (9) are reported in Table 9. Column (1) shows the estimation results with the degree of fiscal support as the threshold variable. When the degree of fiscal support is lower than the threshold value of 0.2073, the coefficient of open-driven is significantly positive, but the value is small. When the degree of fiscal support is higher than the threshold value of 0.2073, the coefficient rises from 2.207 to 4.695 and is still significant. Therefore, when fiscal support crosses a certain threshold value, the government can use subsidies and transfer payments to adjust the cost of capital and improve the business environment. Column (2) presents the results with the degree of talent support as the threshold variable. When talent support is below the threshold value of 0.0251, the coefficient of the external open-driven was 3.123. When the degree of talent support exceeds 0.0251, the regression coefficient rose slightly to 4.382, which reflects that technology spillover can play the maximum effect in the open economy when talent support crosses a certain threshold. The introduced technology can be transformed into independent innovation capacity and finally realize the leap-forward development of the regional economy. Column (3) shows the regression results with the R&D support as the threshold variable. When the R&D support is less than 0.0337, the regression coefficient is 3.526. When the R&D support exceeds 0.0337, the regression coefficient rises to 6.843. It shows that when the local government support for R&D efforts crosses a certain threshold value, it can reduce enterprises' risk of R&D investment and improve the enthusiasm for innovation. By improving productivity and innovation performance, enterprises can enhance market competitiveness and operating profit, thus driving the high-quality development of the regional economy.

We take financial, talent, and R&D policy support measures. Only when the intensity of policy support crosses a certain threshold value can the role of expanding opening to the outside world in promoting regional economic development be fully played. Correspondingly, the curve slope of opening to the economic development function in Fig. 2 is increasing.

5. Conclusion and implications

Based on the panel sample data of 30 provinces in China from 2004 to 2018, this paper applies static and dynamic regression models to examine the relationship between EO and regional economic growth. It uses the mediation and threshold regression effects to conduct a deeper expansion analysis. The main conclusions of this paper are as follows: First, expanding EO is conducive to optimizing regional economic development. The results remain robust after overcoming the effects of endogenous problems. Second, scientific and technological innovation is an important channel for EO to promote regional economic growth. Third, in provinces with different levels of economic development, EO has a heterogeneous impact on regional economic growth. With the improvement of regional economic development level, the role of opening up to the outside world is becoming more and more important. While in regions with very high levels of economic development, its positive role has been weakened. The outbreak of the financial crisis weakened the role of EO on regional economic growth. At the same time, the Belt and Road Initiative strengthened the economic promotion effect of opening up. Fourth, when introducing the threshold variables of policy support to investigate the non-linear relationship, there is only a single threshold value. When a certain threshold value is crossed, the role of EO in stimulating regional economic growth will be greatly strengthened.

The conclusion of this paper has important policy implications for expanding the level of regional EO and maintaining a good momentum of economic growth. First, we should continue to implement the reform and EO policy. Local governments should strengthen top-level design, improve preferential policies for EO, attract strategic investors to invest, and help multinational enterprises "go global". In this process, China should pay attention to preventing risks and the regulatory capacity to adapt to the level of EO. Second, China must adhere to the path of independent innovation with Chinese characteristics. Local governments should attach great importance to scientific and technological innovation, enhance their technology incubation capacity, and seize the opportunities of a new round of scientific and technological revolution. Local governments should encourage enterprises to learn by doing and combining industry-university-research to increase their ability to transform scientific and technological achievements. Finally, local governments should increase government support for finance, talents, and R&D. It is necessary to improve regional scientific and technological innovation to achieve high-quality economic development in the "double-cycle" pattern.

There are some limitations in this paper. First, there are data missing problems in some provinces, which may lead to biased statistical results. Second, we select inter-provincial data for research, resulting in insufficient sample size. Therefore, future research can examine the impact of economic opening on regional economic growth from a microscopic perspective, such as applying city-level or enterprise-level data. Moreover, it is important to explore multiple channels for the impact of EO on Economic Growth.

Declarations

Author contribution statement

Ya Wen: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Pingting Song: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data.

Chen Gao: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Deyong Yang: Contributed reagents, materials, analysis tools or data.

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Table 9
The results for the relationship between policy support and EO.

The threshold variable	(1)	(2)	(3)
	FS	HR	RD
EO_1	2.207*** (0.6539)	3.123*** (0.6824)	3.526*** (0.6358)
EO_2	4.695*** (0.6018)	4.382*** (0.6317)	6.843*** (0.7496)
Control variables	YES	YES	YES
Province effect	YES	YES	YES
Time effect	YES	YES	YES
R^2	0.7810	0.7575	0.7653
N	450	450	450

Note: EO_1 and EO_2 represent the regression coefficients of EO within different threshold intervals.

Declaration of interest statement

The authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.heliyon.2023.e12825.

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