

Technological Innovation Capability and Middle-Income Trap in China - The Mediating Role of Human Capital and Moderating Role of Institutional Environment

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Abstract

Purpose: This paper aims to address the above issues by studying the impact mechanism of technological innovation capability on China's middle-income trap, as well as the mediating role of human capital and moderating role institutional environment, so as to provide a reference for China and other countries to overcome the middle-income trap. **Design/methodology/approach:** This study uses quantitative empirical analysis methods based on panel data and time series to examine the impact of technological innovation capabilities on China's middle-income trap. This study selects the secondary data of China's macro level from 2000 to 2022 to carry out empirical analysis. **Findings:** The results of the study show that technological innovation capacity has a positive effect on China's crossing the middle-income trap, while human capital as a mediator and and the institutional environment as a moderator. **Research limitations/implications:** This study is mainly based on the national-level panel data, which may not be able to fully capture the differences in innovation behavior and institutional environment at the provincial data and micro-enterprise levels, so the selection of variables is limited in dimension. **Practical implications:** The findings of the study provide suggestions for China to cross the middle-income trap and provide reference for the next policy direction. **Originality/value:** The originality of this study lies in the systematic construction of the "technological innovation capability - human capital - institutional environment" mechanism to explain China's middle-income trap problem, which not only expands the theoretical framework, but also provides policy implications that are highly consistent with the national strategy. **Keywords:** Middle-Income Trap, Technological Innovation Capability, Human Capital, Institutional Environment

Introduction

The middle-income trap refers to a situation in which a country, after reaching the middle-income level, is unable to sustain the traditional factor-driven growth model, while a new innovation-driven growth model has not yet been formed, resulting in long-term economic stagnation or even regression. The World Bank points out that the common characteristics of most middle-income economies in trouble are the slowdown in productivity growth, insufficient industrial upgrading and lagging institutional reforms(Gill et al., 2007).

For China, whether it can cross the middle-income trap is not only related to the transformation and upgrading of the economic growth model, but also to its positioning in the global value chain and the shaping of international competitiveness(Wang et al., 2021). In the past four decades, China has achieved rapid economic growth thru reform and opening up and rapid industrialization, and has been firmly in the position of the world's second largest economy(Lu et al., 2019). However, with the rapid increase in per capita income, China's economic growth is transforming from a high-speed to a high-quality stage, and the growth momentum is gradually shifting from factor input-driven to innovation-driven(Wang & Liu, 2023). At the same time, China is also facing structural challenges such as accelerated population aging, tightening resource and environmental constraints, and unbalanced regional development(Zhang et al., 2024). The existence of these contradictions makes how to prevent falling into the middle-income trap a strategic issue for China's economic development at present and in the future.

In recent years, technological innovation has gradually been regarded as the key factor in determining whether a country can break thru the middle-income trap. Schumpeter's innovation theory emphasizes that technological progress and innovation activities are the core driving force for long-term economic growth(Cantwell, 2000); the endogenous growth theory also points out that capital accumulation has a diminishing effect in the long run, while technological progress is the fundamental source of sustained growth(Romer, 1990).

In addition, in the context of diminishing marginal returns of factor inputs, by relying on technological progress and independent innovation can we continuously improve total factor productivity (TFP) and realize the optimization and upgrading of industrial structure. Existing studies have shown that developed countries generally experience a significant increase in R&D investment, a rapid increase in patent output, and institutional improvement of the innovation ecosystem when crossing the middle-income stage(Arezki et al., 2019).

For China, although the scale of R&D investment and the number of patent applications have ranked among the top in the world, there are still shortcomings in the quality and originality of innovation, and the gap in innovation capacity between regions is significant(Zhang, 2023). This means that only the accumulation of innovation in quantity is not enough to ensure that China can successfully cross the middle-income trap, and the efficiency of transforming innovation output into productivity improvement and economic growth is the key(Paus, 2020).

At the same time, human capital is regarded as an important support for the innovation-driven development strategy. On the one hand, the accumulation of high-quality labor force can not only improve the absorption capacity of new technologies, but also improve the

efficiency of R&D and the originality of achievements(Griffith et al., 2004); on the other hand, human capital can further amplify the contribution of technological innovation to economic growth by promoting knowledge diffusion and industrial upgrading(Bye & Fæhn, 2022).

In addition, the institutional environment is also a key condition for determining whether innovation can be transformed into a driving force for growth. The degree of perfection of the system not only affects the incentive mechanism of innovation activities, but also relates to whether the innovation achievements can be smoothly transformed into economic benefits(Bessen & Meurer, 2008). Factors such as property rights protection, government efficiency, and the market competition environment jointly determine the expected return on R&D investment. If the institutional environment is weak, enterprises may lack the motivation to innovate, and R&D results may be difficult to apply or transform due to insufficient protection, thereby weakening the marginal effect of innovation on economic growth(Blanco & Goel, 2023).

Based on the above background, this research intends to construct a comprehensive analysis framework including "technological innovation capability - human capital - institutional environment – middle-income trap", focusing on answering the following core questions: First, can technological innovation capability significantly reduce the risk of China falling into the middle-income trap? Second, does human capital play a mediating role between technological innovation capability and the middle-income trap, so as to explain how innovation is transformed into economic growth? Third, will the institutional environment moderate the marginal effect of technological innovation on economic growth? By answering these questions, this study will not only help deepen the understanding of China's path to cross the middle-income trap, but also reveal the effectiveness and limitations of the innovation-driven development strategy in different institutional environments from the policy level.

Literature Review

Middle-Income Trap

The term middle-income trap was first proposed in the World Bank's "An East Asian Renaissance: Ideas for Economic Growth" published in 2007. The report cited Garrett (2004) and pointed out that middle-income countries face competition from low-wage poor countries and the squeeze from high-income rich countries in technology and mature industries at the same time, and the growth of income is more likely to slow down under the competition of countries among the world.

After the middle-income trap was proposed, scholars also derived different meanings from it. Aiyar et al. (2018); Eichengreen and Gupta (2013); Eichengreen et al. (2014) pointed out in their research based on the modern economic growth theory that a country is considered to have fallen into the middle-income trap if its economic growth rate declines or even stagnates after entering the middle-income stage, and its per capita income cannot reach the standard of high-income countries within a long period; Ye and Robertson (2016) pointed out if the ratio of a country's per capita income to that of the United States tends to be stable for a long time, while the economy belongs to the middle-income country group for a long period, which means that it has fallen into the middle-income trap.

Overall, the relevant literature generally views the middle-income trap as an economic phenomenon that middle-income countries may experience during the development. This means that once a country's economic development level reaches the middle-income stage (between 4,000 and 10,000 US dollars, according to the World Bank's standard), the subsequent driving force for the country's economic growth is insufficient, and the contradictions and problems accumulated in the country's rapid economic development at the early time are concentrated, making it complicated for a country to enter the high-income stage quickly and remain in the middle-income stage for an extended period of time.

Technological Innovation Capability

Technological innovation capability refers to the comprehensive capability of a country, region or organization to realize the creation, application and diffusion of new technologies, new products, new processes and new models thru R&D activities on the basis of knowledge accumulation and resource allocation. Scholars generally believe that technological innovation capability is not only reflected in the investment in scientific and technological research and development, but also includes the output of achievements, the transformation of achievements and their promotion of economic development (Mohamed et al., 2022).

First, from the perspective of knowledge creation and R&D investment, technological innovation capability emphasizes the number of R&D personnel, the intensity of R&D funding, and the R&D activities of scientific research institutions and enterprises, which are the basic conditions for innovation (Li et al., 2024). Secondly, from the perspective of output and diffusion of achievements, innovation ability is reflected in the number of patent applications, the output of high-tech products and the market conversion rate of scientific research achievements, which determines the contribution of innovation to economic competitiveness (Reznakova & Stefankova, 2022; Zhang et al., 2023). Thirdly, from the perspective of the institutional environment and application capabilities, technological innovation not only depends on the innovation subject status of enterprises, but also requires the guaranty of institutional arrangements such as government policy support, intellectual property protection, and financial system. These elements together constitute the external support for innovation capabilities (Wang et al., 2019).

Therefore, technological innovation capability is a multi-dimensional and systematic comprehensive concept, which includes innovation input, reflects innovation output, and emphasizes innovation transformation and environmental support. At the enterprise level, it is an important foundation for maintaining market competitive advantage and sustainable growth; at the national level, it determines the long-term driving force and international competitiveness of economic development (Dhliwayo & Chebo, 2024).

Human Capital

The basic connotation of human capital is to regard the knowledge, skills, health status and experience contained in the labor force as a form of capital (Cm et al., 2023). It was first systematically proposed by Schultz (1960), who believed that human capital is similar to physical capital, and can be accumulated thru investment and has a long-term impact on labor productivity and economic growth.

The academic community generally believes that human capital not only includes education level and skill reserves, but also covers health status, innovation ability and social experience(Barro & Lee, 1993). At the macro level, human capital is regarded as the key driving force for national economic development and an important support for technological progress and industrial upgrading. At the micro level, human capital is manifested as the ability of individuals to create value and improve efficiency in the production process(Becker, 2002).

In addition, with the deepening of research, the extension of human capital has gradually expanded. On the one hand, scholars have emphasized the importance of the structure of human capital, that is, not only to pay attention to the accumulation of quantity, but also to pay attention to quality and level(Zakari & Majid, 2022); On the other hand, in the context of knowledge economy and innovation-driven development, human capital is increasingly regarded as the core factor to promote technological innovation and break thru the middle-income trap(Liu & Huo, 2024).

In summary, human capital is a multi-dimensional and dynamically accumulated concept. It is not only a comprehensive embodiment of education, training and health, but also an important institutional and structural resource for economic growth, social progress and technological innovation.

Institutional Environment

The institutional environment generally refers to the overall framework of formal institutions and informal norms formed in the economic, political and social operation of a country or region(Shah, 2024). North (1990a) defined institutions as "the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction," emphasizing that the institutional environment is composed of formal rules (laws, policies, property rights protection, etc.) and informal rules (culture, customs, values, etc.). It determines the efficiency of resource allocation and affects the market transaction costs, organizational behavior and the effectiveness of innovation activities(Castellacci et al., 2022). The institutional environment is regarded as an important external condition for economic growth and technological progress. A good institutional environment can reduce the uncertainty of innovation and transactions thru property rights protection, the rule of law guaranty and policy incentives, so as to improve the efficiency of resource utilization and total factor productivity(Akbar et al., 2024).

Management and organizational theory further emphasize that the institutional environment not only shapes the competitive rules and market entry barriers for enterprises, but also affects the strategic choices and innovative behaviors of enterprises thru legitimacy pressure and institutional isomorphism(Dickson & Weaver, 2008). As research has expanded, Vargas-Hernandez et al. (2024) proposed that, the extension of the institutional environment has gradually extended to broader levels such as governance quality, institutional enforcement, social trust levels, and innovation-friendly.

Therefore, the institutional environment can be defined as a comprehensive and multi-dimensional external institutional system, which shapes the incentive and constraint mechanism of economic and social behavior thru the interaction of laws, policies, culture and

social norms, and is an important institutional guaranty for technological innovation, human capital accumulation and economic growth.

Underlying Theory

This study mainly constructs the overall analysis framework based on the endogenous growth theory, human capital theory and institutional theory. Firstly, the endogenous growth theory points out that technological innovation is the core driving force for sustained economic growth(Barbier, 1999). Thru knowledge accumulation, R&D spillover and productivity improvement, technological innovation capability can help the economy break thru the development bottleneck and realize the transformation from factor input to innovation-driven(Wang et al., 2023).

Secondly, the human capital theory emphasizes that the skill structure and education level of the labor force are the important basis for the absorption, diffusion and transformation of innovation achievements into actual economic benefits, and the high-level human capital can significantly improve the efficiency and application depth of technological innovation(Aldieri et al., 2019).

On this basis, the institutional theory(Tina Dacin et al., 2002) further points out that the institutional environment plays a dual role of constraint and incentive in the process of economic development, and jointly affects innovation incentives, human capital investment returns and factor allocation efficiency thru formal institutions such as property rights protection, rule of law quality, policy stability, and innovation support mechanisms, as well as informal institutions such as culture and social norms. A good institutional environment can strengthen the interaction between technological innovation and human capital, improve the efficiency of innovation transformation, and make innovation momentum more smoothly transmitted to economic growth(Sein & Rehman, 2025).

Based on the above theory, this study proposes that technological innovation capability not only directly affects the quality of economic development, but also can play an mediating role thru the formation of human capital; at the same time, the institutional environment plays a key moderating role in the transmission process of technological innovation to human capital accumulation by affecting innovation incentives and human capital returns.

Hypothesis Development

The proposed framework comprises three concepts. The variables (IV) are technological innovation capability, while the middle-income trap serves as the dependent variable (DV) in this study. Human capital serves as the mediating variable, and the institutional environment serves as the moderating variable. Based on previous research, we construct H1, H2 and H3, to understand the relationship between China's technological innovation capability and the middle-income trap.

Relationship between Technological Innovation Capability and Middle-Income Trap

Studies have found that China's technological innovation capabilities have greatly affected its potential to escape the middle-income trap(Li & Zhao, 2024; Wang et al., 2021). After economic development enters the middle-income stage, the growth mode driven by low-cost labour and factor input is difficult to sustain. By relying on technological progress and

industrial upgrading can maintain long-term competitive advantages(Lin & Wang, 2020). By enhancing endogenous innovation capacity, China is well placed to overcome obstacles such as high productivity, income distribution issues and environmental challenges, and it is crucial for local innovation and skilled labour to transition from middle-income to high-income status. However, despite China's leadership in incremental innovation, the country's current creative output still lags behind. Lu (2018) study highlights that China risks stagnation if it does not make significant reforms to education, financial regulation and the business environment. Based on the above, the following hypothesis is proposed:

H1: There will be a positive relationship between technological innovation capability and middle-income trap.

Mediating role of human capital on technological innovation capability and middle-income trap

According to the endogenous growth theory(Lucas Jr, 1988; Romer, 1990), human capital is not only the core driving force of economic growth, but also an important condition for the transformation of technological innovation achievements into productivity improvement. Agénor (2017) argues that insufficient human capital quality is a key factor in the middle-income trap because it hinders innovation. While imitation can promote short-term economic growth in the early stages of economic development, the transition to sustainable economic development requires a skilled and high-level workforce. Low-quality human capital limits the ability to adopt new technologies and processes, thereby preventing countries from escaping low or medium growth equilibrium(Osei, 2024). Therefore, enhancing human capital is critical to promoting technological innovation and overcoming the challenges posed by the middle-income trap. Based on the above, the following hypothesis is proposed:

H2: There will be a significant mediating effect of human capital between technological innovation capability and middle-income trap.

Moderating role of institutional environment on technological innovation capability and middle-income trap

The institutional environment is an important institutional constraint that affects a country's innovation capacity and the effectiveness of its economic transformation(North, 1990b). In the process of innovation-driven development, the institutional environment not only determines the incentive and constraint mechanism of innovation activities, but also affects the transformation and diffusion efficiency of innovation achievements (Acemoglu et al., 2012).

Specifically, a good institutional environment can provide stable expectations and institutional guaranties for technological innovation by strengthening intellectual property protection, improving market competition mechanisms, improving the effectiveness of government governance, and creating a fair and transparent business environment (Hall & Jones, 1999). In this context, technological innovation is more likely to promote industrial upgrading and productivity improvement, thereby significantly reducing the risk of falling into the middle-income trap(Inui, 2015).

On the contrary, if the institutional environment is unsound, it may lead to insufficient innovation incentives, inefficient resource allocation, and even frequent "rent-seeking" and corruption, thereby weakening the positive effect of technological innovation on economic

development and making it difficult to effectively transform technological innovation capabilities into the driving force for crossing the middle-income trap (Blanco & Goel, 2023). It can be inferred that the institutional environment plays a regulatory role in the relationship between technological innovation capability and the middle-income trap. Based on the above, the following hypothesis is proposed:

H3: There will be a significant moderating effect of institutional environment between technological innovation capability and middle-income trap.

The proposed model presented as follows:

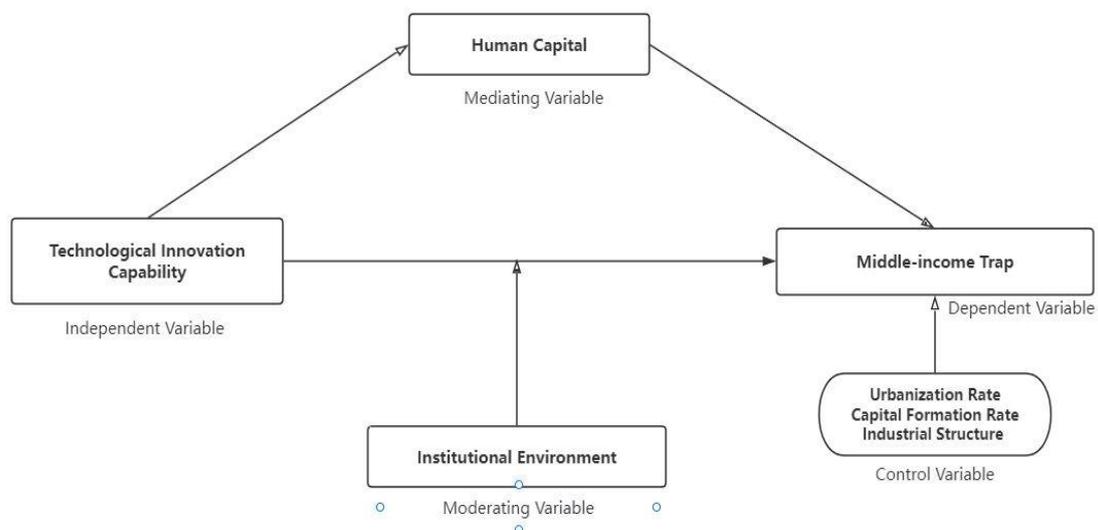


Figure 1 Research Framework

Methods

Research Design

In the empirical study, this study was carried out according to the following steps. First, based on the existing theories and relevant literature, the research model and hypothesis are proposed, and the action mechanism of the dependent variable, independent variable, mediating variable and moderating variable is clarified. Secondly, this study select appropriate data sources, measure each variable, and introduce necessary control variables to reduce the bias of missing variables. Then, descriptive statistics and correlation analysis are conducted to preliminarily test the relationship between variables and the problem of multicollinearity.

In the empirical analysis stage, the direct effect of the independent variable on the dependent variable was first tested thru the regression model; then the mediating effect was tested, and the Bootstrap method was used to evaluate the significance of the indirect effect. This method is more robust than the traditional three-step regression method (Baron & Kenny, 1986). For the moderating effect, the interaction term is introduced into the regression model to test whether the moderating effect is significant, and the simple slope analysis is further used to reveal the effect difference under different situations (Aiken et al., 1991). In addition,

to ensure the reliability of the conclusions, this study also conducted robustness tests, including changing the measurement of variables and sample grouping. Finally, the empirical results are interpreted, and compared and discussed with the existing research, so as to draw theoretical and practical implications.

Sample Selection

This study takes China as the research object, and chooses the whole country of China as the object of studying the middle-income trap, rather than focusing only on the eastern region or a certain province, which has many theoretical and practical significance. First, there are obvious regional differences and unbalanced development in per capita income, service industry development, human capital accumulation, and institutional environment in various regions of China (Deng et al., 2022). The obstacles faced by the central and western regions and the northeast region in the process of moving toward the high-income stage are essentially different from those of the eastern coastal areas. Studying the eastern region will ignore the systemic challenges of the country as a whole in crossing the middle-income trap (Kanbur & Zhang, 1999). Second, from the perspective of policy significance, China's national development strategy (such as the "Regional Coordinated Development Strategy" and "Common Prosperity") emphasizes the overall promotion at the national level (Li et al., 2023). The empirical analysis of the national sample helps to provide more universal and targeted empirical evidence for the institutional design at the central level.

This study constructs a time series data from 2000 to 2022, with a total of 23 annual observations. The reason for choosing this time range is that China has entered a stage of rapid industrialization and urbanization since 2000, and its technological innovation capabilities have been significantly improved. The problem of the middle-income trap has gradually become the focus of attention in the academic and policy circles. On the other hand, the relevant statistical data are relatively complete during this period, which is convenient for carrying out systematic analysis.

Variables Measurement

By combining the existing research and the research objectives of this paper, it is found that the following indicators are most widely used in empirical research.

Dependent variable MIT: The measurement of the middle-income trap adopts the per capita gross national income (GNI, current price and PPP adjustment), and the data comes from the World Bank's World Development Indicators (WDI) database;

Independent variable TIC: The measurement of technological innovation capability uses the comprehensive index of technological innovation, including R&D investment intensity (R&D/GDP) and the number of invention patent authorizations, and the data comes from the World Bank database and WIPO respectively;

Mediating variable HC: The human capital index is mainly measured by the proportion of the population graduating from higher education, and the data comes from the China Statistical Yearbook;

Moderating variable IE: The institutional environment variable uses the sub-items of the World Governance Indicators (WGI), such as Government Effectiveness, Rule of Law, and Control of Corruption.

Control variables C: Urbanization rate, capital formation rate, industrial structure. The data mainly comes from the National Bureau of Statistics of China and WDI.

In data processing, this paper logarithmically processes the indicators with high skewness (such as the number of patents). For missing years, linear interpolation or comparison with data from third parties was used to supplement the data. Finally, a time series data of 23 years was formed for regression and mechanism test.

Table 1
Variables and Data Sources

Type	Variable	Symbol	Description	Data Source
Dependent	Middle-income trap	MIT	Measured by GNI per capita (current PPP-adjusted values)	World Bank WDI
Independent	Technological innovation capability	TIC	Composite innovation index including R&D/GDP and granted invention patents	WDI, WIPO
Mediator	Human capital	HC	Share of population with higher education attainment	China Statistical Yearbook
Moderator	Institutional environment	IE	Sub-indicators of the Worldwide Governance Indicators (government effectiveness, rule of law, control of corruption)	WGI
Controls	Urbanization rate, gross capital formation, industrial structure	UR; GCF ; IE	Reflecting macroeconomic and structural factors	NBS, WDI

Source: Author

Model Setting

1. In order to test the mechanism of the role of technological innovation capability in crossing the middle-income trap, this study established the (a) model for testing:

$$MIT_t = \alpha + \beta_1 TIC_t + \gamma' C_t + \epsilon_t \quad (a)$$

α is a constant term; β_1 is the regression coefficient of the core explanatory variable, indicating the marginal impact of each unit increase in innovation capability on MIT_t ; γ' is the coefficient set of the control variable; and ϵ_t a random disturbance term.

2. In order to test the mediating path of TIC→HC→MIT, this study used the regression step-by-step method and the Bootstrap method to estimate the significance and confidence interval of the mediating effect, and constructed the mediating models of (b) and (c):

$$HC_t = \alpha_0 + aTIC_t + \pi' C_t + \eta_t \quad (b)$$

$$MIT_t = \delta_i + \delta' TIC_t + HC_t + \gamma' C_t + v_t \quad (c)$$

If both a , b and δ' are significant, there is a partial mediating effect; If both a , b are significant but δ' is not significant, there is a complete mediating effect.

3. In order to test whether the institutional environment (IE) regulates the impact of TIC on MIT, this study constructs the adjustment model (d):

$$MIT_t = \alpha_i + \delta_t + \beta_1 TIC_t + \beta_2 IE_t + \beta_3 (TIC_t \times IE) + \gamma' C_t + \varepsilon_t \quad (d)$$

β_3 is the key coefficient; if it is significant, it indicates that the effect of technological innovation capability on Y changes with the level of institutional environment.

Findings

Table 2

Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Middle-income trap	0.553	0.172	0.31	0.81
Technological innovation capability	42.85	9.96	25.4	60.7
Human capital	0.703	0.094	0.52	0.85
Institutional environment	0.615	0.102	0.43	0.78
Urbanization	58.21	11.73	36.2	75.3
Capital formation	43.82	3.71	38.7	49.5
Service sector share	51.63	5.82	40.3	59.4

Source: Author

The overall data is stable and the volatility is reasonable, indicating that the variables have good comparability and explanatory power.

Table 3

Baseline Regression Results

Variable	Coefficient	Std. Error	t-value	p-value
Technological innovation capability	-0.184***	0.053	-3.49	0.002
Urbanization	-0.112**	0.046	-2.41	0.025
Capital formation	-0.078	0.051	-1.52	0.144
Industrial structure	-0.093**	0.041	-2.27	0.033
Constant	0.841***	0.127	6.62	0.000
R ²	0.678			
N	23			

Source: Author

The technological innovation capability has a significant negative impact on the middle-income trap index ($\beta = -0.184$, $p < 0.01$), indicating that the improvement of technological innovation capability significantly promotes China's crossing of the middle-income stage. The sign direction of control variables such as urbanization rate and industrial structure is in line with expectations, indicating that structural upgrading and urbanization are equally important for alleviating the middle-income trap.

Table 4
Mediation Effect of Human Capital

Variable	(1) MIT	(2) Human Capital	(3) MIT (with mediator)
Technological innovation capability	-0.184***	0.296***	-0.118**
Human capital	—	—	-0.241***
Controls	Yes	Yes	Yes
R ²	0.678	0.603	0.724
N	23	23	23

Source: Author

Technological innovation capability significantly promotes the accumulation of human capital ($\beta = 0.296$, $p < 0.01$). When human capital is introduced into the model, the absolute value of the coefficient of technological innovation capability decreases, indicating that there is a partial mediating effect. The Bootstrap test shows that the indirect effect is -0.066 , and the confidence interval $[-0.119, -0.028]$ does not contain zero significantly.

Table 5
Moderation Effect of Institutional Quality

Variable	Coefficient	Std. Error	t-value	p-value
Technological innovation capability	-0.142**	0.059	-2.41	0.026
Institutional environment	-0.089	0.064	-1.39	0.179
TIC \times IE	-0.112**	0.048	-2.33	0.032
Controls	Yes			
R ²	0.717			
N	23			

Source: Author

The interaction term is significantly negative (-0.112 , $p < 0.05$), indicating that the improvement of the institutional environment can strengthen the positive effect of technological innovation capability on economic leap. When the system is more rule-of-law, more transparent, and the government is more effective, the economic transformation efficiency of technological innovation capability is significantly improved.

Table 6
Robustness Tests

Model	TIC Coefficient	R ²	Method
Baseline OLS	-0.184***	0.678	—
Using R&D/GDP only	-0.176***	0.672	Variable substitution
One-year lag of Innovation	-0.161**	0.648	Endogeneity control
ARDL long-term model	-0.172**	0.655	Dynamic robustness
Excluding 2008–2009	-0.179***	0.670	Sensitivity test

Source: Author

The results of each model are consistent in direction and stable in significance, indicating that the empirical conclusion has strong robustness.

Based on the time series data of China's national level from 2000 to 2022, this study conducts an empirical analysis, and the main findings are as follows:

(1) Technological innovation capability has a significant negative impact on the middle-income trap, indicating that improving technological innovation helps China to cross the middle-income trap.

(2) Human capital plays a partial mediating role between technological innovation and the middle-income trap: technological innovation capability not only directly reduces the risk of the trap, but also indirectly alleviates the middle-income trap by increasing the proportion of the population with higher education and the quality of R&D personnel.

(3) The institutional environment shows a positive moderating effect in the path of technological innovation capability on human capital, that is, the promotion effect of technological innovation capability on human capital is stronger when the business environment is better and the quality of government governance is higher.

(4) After controlling for factors such as urbanization rate, capital formation rate, and industrial structure, the main conclusions are still robust.

Discussion and Conclusion

This paper explores the impact mechanism of technological innovation capability on China's middle-income trap, and introduces human capital as an intermediary variable and institutional environment as a regulatory variable. The main conclusions are as follows: technological innovation is the key driving force for China to cross the middle-income trap, and its role is not only reflected in directly promoting economic growth, but also plays an indirect effect thru the improvement of human capital. At the same time, a good institutional environment can amplify the positive effect of technological innovation on human capital, thereby further reducing the risk of the middle-income trap.

Theoretical Implications

Firstly, this paper finds that technological innovation is a key driver for promoting sustained economic growth and helping countries to cross the middle-income trap, which is consistent with the endogenous growth theory (Romer, 1990) and the view of Acemoglu (2008) that innovation promotes long-term productivity improvement. A large number of empirical studies have also confirmed the negative correlation between innovation capacity and the middle-income trap. For example, Eichengreen and Gupta (2013) pointed out that improving a country's innovation capacity can significantly reduce the risk of falling into income stagnation. The empirical results of this study are consistent with these studies and provide more targeted evidence based on Chinese data.

Secondly, this paper verifies the mediating role of human capital in the process of technological innovation affecting the middle-income trap, which not only echoes the theoretical framework of Lucas Jr (1988) that "human capital deepening promotes growth", but also is consistent with recent empirical studies on China. This study further shows that technological innovation can not only directly promote economic growth, but also play an

indirect effect by promoting the accumulation of human capital, thereby strengthening the upgrading of economic structure.

Finally, the study found that the institutional environment has a significant positive regulatory effect on the relationship between technological innovation and human capital. This result is consistent with the theory of new institutional economics that the quality of institutions affects the efficiency of resource allocation (North, 1990a). Previous studies have also pointed out that improved property rights protection, marketization, and innovation incentive mechanisms can strengthen the efficiency of human capital transformation of innovation achievements (Akbar et al., 2024). The results of this paper further prove that in regions with a better institutional environment, technological innovation has a stronger promoting effect on the level of human capital, which helps to reduce the risk of the middle-income trap.

Practical and Social Implications

This study not only contributes to theory but also offers practical implications for policymakers, institution revolution and society. The research results show that China needs to improve its technological innovation capabilities and human capital level in the process of breaking thru the middle-income trap. In terms of policy, R&D investment should be increased, the education system should be optimized, and the combination of production, learning and research should be promoted to realize the effective transformation of knowledge and skills. Secondly, this study provides guidance for institutional reform. Paying attention to the regulatory effect of the institutional environment can enable China to further carry out market-oriented reforms and protect intellectual property rights, thereby providing a good institutional environment for technological innovation. In addition, this study emphasizes the key role of human capital, indicating that narrowing the imbalance of educational resources and improving the skills and innovation capabilities of workers are important ways to promote social equity and shared development.

Limitations and Suggestions for Future Research

First, this study is mainly based on the national panel data, which may not fully capture the differences in innovation behavior and institutional environment at the provincial data and micro-enterprise levels. In the future, it can be further analyzed in combination with the data at the provincial level. Second, the ability of technological innovation is mainly measured by innovation input and output indicators, but these indicators can hardly fully reflect the quality of innovation and the actual conversion rate. In the future, more refined innovation performance indicators can be used in the future. Third, this study takes the institutional environment as a single regulatory variable, but the institution itself is multi-dimensional and dynamic. In the future, more detailed institutional dimension analysis can be carried out. Finally, this study does not take into account the important impact of globalization, geopolitical risks and technological changes on China's crossing of the middle-income trap. In the future, international comparisons or external shock factors can be introduced.

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