The Coordinated Development of Industry, Academia and Research and China's Economic Growth: Theory and Empirical Evidence

Jiayi Fang

Zhejiang University of Technology, Hangzhou, China.

523759918@qq.com

Abstract. This article takes the coordinated development of industry, academia and research as the entry point and systematically analyzes its impact on China's economic growth. By sorting out the relationship between industry-university-research collaboration and economic growth, a relevant theoretical analysis framework was constructed. Based on the panel data of 30 provinces in China from 2009 to 2022, this article empirically examines and analyzes the specific role and influence path of industry-university-research collaboration on economic growth by using the entropy weight method and the coupled coordination model. The results of the empirical analysis show that the coordinated development of industry, academia and research can effectively promote China's economic growth, and its influence is significantly regulated by the development level of the technology market and the government's investment level in science and technology. He heterogeneity analysis results of the eastern, central and western regions show that the synergy among industry, academia and research has the most obvious promoting effect on economic growth in the central region, followed by the eastern region, while the effect in the western region is not significant. The differences among the three regions are obvious and there is an urgent need for precise policy support. Based on this, this article puts forward relevant policy suggestions for promoting the coordinated development of industry, academia and research, including strengthening government policy support, improving the construction of the technology market, and implementing the regional differentiation strategy, etc. This study expands the analytical perspective on the relationship between industry-university-research collaboration and economic growth, providing new empirical evidence and policy implications for promoting high-quality economic development in China.

Keywords: Industry-University-research collaboration; Economic growth; Regional heterogeneity; Policy recommendations.

1. Introduction

The current global economic environment is experiencing unprecedented uncertainties. On the one hand, at the international level, sluggish growth coexists with inflation risks, trade protectionism is on the rise, various political and military crises occur frequently, and the long-term challenges of climate issues and an aging population structure are increasingly emerging. On the other hand, the domestic economy is also confronted with structural problems such as shrinking market demand, obstruction of key links in the industrial chain, and a decline in enterprises' willingness to invest. However, as the world's largest developing country and the second-largest economy, China, supported by stable economic growth and a huge market scale, still maintains a good momentum of development and is steadily transitioning from a stage of high-speed growth to a stage of high-quality development. With the deepening of China's economic system reform and the advancement of building a moderately prosperous society in all respects, China's economic aggregate has reached a new level, its structure has been optimized and upgraded, and new growth drivers have been constantly emerging. Among them, the deep integration of industry, academia and research has empowered new quality productivity, and new quality productivity has driven productivity to leap towards high efficiency and innovation, thereby promoting China's economy to continue to develop in a high-quality direction with strong growth momentum and obvious resilience.

The 14th Five-Year Plan clearly states that it is necessary to "promote the concentration of all kinds of innovation resources in enterprises and accelerate the construction of a technological innovation system with enterprises at the core, the market as the driving force, and in-depth collaboration among industry, academia, research and application." The development model of collaboration among industry, academia and research has been widely promoted and practiced in China, becoming an important force driving economic growth and having strategic significance for promoting economic development and social progress. As a major economic province, Zhejiang adheres to innovation-driven development, strengthens the exploration and practice of the coordinated development model of industry, academia, research and application, and has built science and technology parks including Zhejiang National University Science Park, Hangzhou National High-tech Industrial Development Zone and Ningbo National High-tech Industrial Development Zone. We have developed a number of landmark achievements such as ultra-high molecular weight polyethylene fibers, the "MinDie" optimization solver, and the "BaGuan" meteorological large model. These successful cases of industry-university-research cooperation have helped transform more and more cutting-edge innovations into new productive forces, bringing social and economic benefits and promoting the development of science and technology and economy in Zhejiang. However, although a large number of scientific research achievements have been applied in practice, nearly 80% of them remain idle. There are still some insufficient understandings in the process from the application of scientific and technological achievements to their transformation into commodities and achieving certain economic benefits, and then to the actual formation of large-scale production, which leads to the fragmentation of the new model of industry-university-research collaboration.

Therefore, this article unfolds from two dimensions: theoretical research and empirical analysis, aiming to study the intrinsic connection between the coordinated development of industry, academia and research and China's economic growth. Previously, the academic community has carried out relevant research in the aspect of collaborative innovation among industry, academia and research. For instance, from the initially constructed theoretical framework of industry-university-research collaborative innovation with the triple interaction of "strategy - knowledge - organization" (He Yubing, 2012), to the three-dimensional Logistic dynamic analysis model of industry-university-research collaborative innovation that evolved to enhance the dynamic collaborative ability of the innovation system (Ye Weiwei et al., 2015), Then there is the tripartite evolutionary game model of industry-university-research collaborative innovation that analyzes the impact of strategy selection through optimization and upgrading (Wu Jie et al., 2019). Liu Youjin et al. (2017) mainly conducted an empirical analysis on 11 provinces and municipalities along the Yangtze River to study the impact of the synergy degree of the industry-university-research innovation system on regional innovation performance. The results were positive and had a significant impact. However, at present, most of the research in the academic circle focuses on the relationship between collaborative innovation among industry, academia and research institutions and the performance of innovation capabilities. There is a lack of empirical analysis of the social and economic benefits brought about by the transformation of scientific and technological achievements, as well as in-depth exploration of the impacts brought about by the collaborative development of industry, academia and research institutions. Moreover, the existing research still remains at the data analysis of specific regions (such as the Yangtze River Delta, the Pearl River Delta and other economically developed areas), and has not conducted a more systematic and comprehensive comprehensive consideration of each province with unbalanced economic development. Therefore, this article selects panel data covering 30 provinces in China from 2009 to 2022, and for the first time studies the impact of the coordinated development of industry, academia and research on China's economic growth on a national scale, expanding the scope of existing research. Therefore, this article explores the intrinsic influence and mechanism of the coordinated development of industry, academia and research on China's economic growth, which has certain theoretical and practical significance. From a theoretical perspective, the analytical model of China's economic growth in the academic circle has been established and tends to be complete. However, the important variable of the coordinated development of industry, academia and research has not yet been included in the consideration index system, and its importance has not been fully explored. Therefore, this study conducts relevant work in the hope of filling the gap. From a practical perspective, if the promoting effect of the coordinated development of industry, academia and research on China's economic growth is confirmed, the deep integration of the three parties can effectively integrate resources, achieve complementary advantages, and thereby promote high-quality economic development in China, which has certain reference value for policy-making.

The main innovation points of this article are reflected in three aspects: First, in terms of topic selection, this article breaks through the framework limitations of traditional research on China's economic growth model. Starting from the innovation subjects and based on the current situation of the deep integration of industry, academia and research, it fills the theoretical gap between the coordinated development of industry, academia and research and China's economic growth. Secondly, in terms of the research perspective, taking the new core variable of industry-university-research collaboration and the degree of coupling coordination as the entry point, the relationship and mechanism of action between the collaborative development of industry-university-research and China's economic growth were explored. Finally, in terms of research implications, the empirical results of this article not only verify the significant promoting effect of the coordinated development of industry, academia and research on China's economic growth, but also reveal the regional differences among various provinces in China and the effect of the eastern, central and western regions, providing a theoretical basis for the government to design differentiated and customized policy measures for different regions.

2. Literature Review and Theoretical Analysis

Technology is one of the core driving forces for economic growth, continuously driving economic development through paths such as enhancing production efficiency, promoting innovation and entrepreneurship, and driving the growth of the digital economy. First, technological innovation and digital empowerment have led to a significant increase in production efficiency. With the emergence of the Third Technological Revolution, information technology, including Internet technology, has significantly enhanced the overall productivity of cities and the manufacturing industry at multiple levels, especially the improvement of manufacturing efficiency (Huang Qunhui et al., 2019). By means of reducing transaction costs, optimizing resource allocation and technological innovation optimization, promote the upgrading and transformation of industries such as manufacturing (global industrial robots) and agriculture (unmanned aerial vehicle plant protection technology), thereby driving economic growth. For instance, from the perspective of adjusting the skill structure of the labor force, artificial intelligence can complete most repetitive tasks with low technical content, reduce the demand of enterprises for low-skilled employees, optimize the personnel structure of enterprises, and thereby enhance the production efficiency of enterprises (Yao Quanzhuang et al., 2024). Second, the empowerment of technological innovation platforms has led to the emergence of entrepreneurial enterprises. Information technology is a key engine for enhancing enterprise innovation and thereby generating new quality productivity. It promotes enterprise innovation and entrepreneurship through three mechanisms: increasing knowledge diversity, breaking organizational conventions, and improving the efficiency of resource allocation (Li Yuhua et al., 2024). The third is that the digital economy reshapes the growth structure. The disruptive changes in technology and industry have brought about a new business form, the digital economy. Existing research shows that the digital economy has a significant promoting effect on the upgrading of the industrial structure and will continue to integrate with the real economy, driving economic and social development (Wang Xiaowen et al., 2022).

Technology promotes economic development through certain paths, and the collaboration among industry, academia and research is an important driving force for the transformation of technology into economic value. Therefore, the coordinated development of industry, academia and research has complex impacts in multiple aspects. The academic community has conducted multi-dimensional research on the impact of industry-university-research collaboration: Firstly, in terms of theoretical value, strengthening industry-university-research collaborative innovation is the key to the integration of the science and technology economy and the knowledge economy. Through strategic collaboration, the innovation ability of enterprises can be enhanced; through knowledge collaboration, knowledge transfer and sharing can be strengthened; and through organizational collaboration, the efficiency level of cooperative innovation can be improved (He Yubing, 2011). Secondly, in terms of the practical path, strategic alliances are established to achieve the effect of promoting collaborative innovation among industry, academia and research. This model strengthens the role of collaborative innovation, helps to combine top-level and systematic aspects, comprehensively integrate and optimize the allocation of resources, stimulate internal motivation while adapting to external demands, cultivate the ability for sustainable development, and create a favorable policy environment and social atmosphere (Zhang Li, 2011). Then, in terms of empirical effects, the academic community has long confirmed the positive role of industry-university-research cooperation in patent output and the quality of innovation achievements, and then innovatively proposed its influence in breakthrough innovation. Through the diffusion of scientific knowledge and complementary resources, industry-university-research cooperation expands the breadth and depth of enterprise knowledge and effectively helps enterprises improve the quality of innovation (Liu Feiran and Li Shijie, 2025). From a macro perspective, based on symbiotic networks and small-world networks, a new type of industry-university-research collaborative innovation model was constructed, and the collaborative effect of industry-university-research and its optimization of the knowledge transfer path were evaluated and verified. From a micro perspective, promoting collaborative innovation among industry, academia and research has optimized the cultivation model of innovative talents and provided a favorable environment for the emergence of innovative talents.

Therefore, this study holds that the collaborative development mechanism of industry, academia and research has a direct promoting effect on economic growth. The core of industry-university-research cooperation lies in the synergy effect, mainly through the complementary advantages and resource integration among the three main bodies of enterprises, universities and research institutions, to form an innovative synergy. Specifically, universities, relying on their unique advantages in human resources, undertake the main responsibilities in the initial stage of theoretical research and lay a solid foundation for the development and implementation of technological achievements. Research institutions lie between the two, playing a pivotal role in connecting the past and the future. They are mainly responsible for completing crucial technological breakthroughs and overcoming difficulties to form feasible scientific and technological achievements. On the basis of fully understanding market demands and proficiently operating business capabilities, enterprises carry out commercial development and transformation of achievements, and ultimately achieve profitability. In conclusion, this chain mechanism of "basic research - application development - commercial promotion" for the coordinated development of industry, academia and research not only significantly improves the utilization rate of previously idle and undevelopable scientific and technological resources, but also innovatively expands a new path for scientific and technological achievements to move from the laboratory to the production line. While promoting the smooth transformation of scientific and technological achievements into production, efforts should be made to encourage the target industry to expand production capacity, improve production efficiency, and accelerate the formation of new quality productive forces, thereby empowering economic growth.

In addition, the promoting effect of the coordinated development of industry, academia and research on the economy is significantly reflected in many practical cases, taking the Shenzhen Research Institute of Tsinghua University as an example. It has pioneered a new model of integration among industry, academia and research, deeply analyzing high-tech achievements, exploring the characteristics of these products that can be developed and commercialized, then connecting with target industries, implementing a series of standardized application testing processes, and finally launching them to the market. Data shows that more than 15 key achievements are industrialized each year, and the direct economic benefits output exceeds 500 million yuan. This model has contributed to the formation of a virtuous cycle where "scientific research creates value and value feeds back to scientific research", activated a favorable regional innovation mechanism, and enabled the regional economy to achieve leapfrog growth.

To sum up, this article proposes Hypothesis 1: The coordinated development of industry, academia and research has a promoting effect on economic growth.

The promoting effect of the coordinated development of industry, academia and research on economic growth is largely influenced by the development level of the technology market. One of the important platforms on which the collaboration among industry, academia and research relies is the technology market. The demand for technological innovation is the driving force that prompts the three entities to reach cooperation, and the smooth transformation of technological achievements is the ultimate goal that the collaboration among industry, academia and research pursues. Therefore, the development of the technology market plays a key role in the influence mechanism of the collaboration among industry, academia and research on the economic market. On the one hand, enterprises maintain a strong interest in high and new technologies in order to enhance their own competitiveness. The continuous development of the technology market provides a market driving force for achieving collaborative innovation among industry, academia and research. On the other hand, science and technology are the primary productive forces. A sound development level of the technology market is conducive to the development of advanced production, thereby promoting economic growth. For instance, the advent of the Third technological revolution marked by information technology, as a catalyst for the technology market, has driven the establishment of Stanford University and its supporting industrial park in Silicon Valley, the United States. On this basis, a collaborative system of industry-university-research cooperation closely integrating universities and enterprises has been formed, which has further optimized and upgraded the related industrial chain, effectively promoting the transformation of new technologies from research and development to commercialization, and has become a global high-tech industrial cluster. Silicon Valley still holds a leading production position globally, generating significant social and economic benefits. Its leapfrog transformation of the industry-university-research ecosystem model is undoubtedly closely related to the explosive innovation in the technology market at that time.

Based on this, this paper proposes the following hypothesis 2: The promoting effect of the coordinated development of industry, academia and research on economic growth is influenced by the development level of the technology market.

The government's emphasis on science and technology also plays a moderating role in the impact of the coordinated development of industry, academia and research on economic growth. Existing studies in the academic circle have pointed out that the government plays an important role in promoting the collaborative and innovative development of industry, academia and research. Its support methods mainly include policy support and financial input, etc. (Hong Yinxing, 2014). However, previous studies often focused on analyzing the synergy mechanisms among the three main bodies of the government, enterprises, universities and research institutions. They did not take "the degree of the government's emphasis on science and technology" into consideration, nor did they conduct in-depth discussions on the regulatory role of the government from the perspective of the coordinated development of industry, academia and research and economic growth. In fact, the degree to which the government attaches importance to science and technology is directly related to its policy inclination, institutional guarantee and support for this innovative model, and directly affects the level of market activity and the potential willingness of market entities. When the government gives top priority to the development of science and technology, it can enhance the cooperation enthusiasm and synergy efficiency of the three main bodies of industry, academia and research through multi-dimensional means such as political subsidies and institutional incentives, and magnify their comprehensive driving effect on economic growth.

Based on this, this paper further proposes Hypothesis 3: The government's emphasis on science and technology plays a moderating role in the impact of the coordinated development of industry, academia and research on economic growth.

3. Empirical Design

3.1 Model

To test the impact effect and action path of the collaborative development of industry, academia and research on economic growth under Hypothesis 1, this paper constructs a model as shown in Equation (1) :

$$Gdpp_{sn} = \alpha_0 + \alpha_1 Ccd_{sn} + \delta_s + \varphi_n + \varepsilon_{sn} \quad (1)$$

Among them, variable s and variable n are adopted respectively for each province and year in China. Gdpp stands for Gross domestic Product per capita and is used to measure the level of economic development. Ccd represents the coupling and coordination degree of industry, academia and research, reflecting the level of coordinated development of industry, academia and research. X represents the set of control variables that affect the level of economic development, making the results more rigorous and reducing interference. α_0 represents a constant term, while α_1 and ϕ represent unknown coefficients. δ_s represents the regional effect brought about by different provinces, and φ_n represents the temporal effect brought about by different years. Finally, ε_{sn} represents the random error term.

However, it is obvious that apart from the level of coordinated development of industry, academia and research that is the focus of this article, there are many other factors influencing economic growth, and the measurement and standards of this in the academic circle are also different. Therefore, based on a comprehensive analysis of existing research and its own reflection and summary, this paper unfolds from six aspects: employment structure, urbanization level, scale of fiscal expenditure, degree of foreign trade, population density and consumption capacity, and formulates a series of control variables represented by X to be introduced into the model, as shown in Equation (2) :

$$Gdpp_{sn} = \alpha_0 + \alpha_1 Ccd_{sn} + \sum_i \chi_i X_{jsn} + \delta_s + \varphi_n + \varepsilon_{sn} \quad (2)$$

Hypothesis 2 and Hypothesis 3, on the basis of affirming the impact of the coordinated development of industry, academia and research on economic growth, introduce two new moderating variables, "the development level of the technology market" and "the government's emphasis on science and technology". Meanwhile, in order to make the moderating effect more credible, this paper constructs the related interaction terms and incorporates them into the model, including the interaction term between the transaction volume of the technology market and the per capita gross domestic product, and the interaction term of the proportion of fiscal science and technology expenditure in total fiscal expenditure. The model is constructed as shown in Equations (3) and (4) :

$$Gdpp_{sn} = \beta_0 + \beta_1 Ccd_{sn} + \beta_2 Ccd_{sn} \times Tvg_{sn} + \beta_3 Tvg_{sn} + \sum_i \chi_i X_{isn} + \delta_s + \varphi_n + \varepsilon_{sn} \quad (3)$$

$$Gdpp_{sn} = \lambda_0 + \lambda_1 Ccd_{sn} + \lambda_2 Ccd_{sn} \times Stf_{sn} + \lambda_3 Stf_{sn} + \sum_i \chi_i X_{isn} + \delta_s + \varphi_n + \varepsilon_{sn} \quad (4)$$

Among them, β_0 and λ_0 represent constant terms, and β_1、β_2、β_3 and λ_1、λ_2、λ_3 all represent unknown coefficients. And Tvg_{sn} and Stf_{sn} respectively represent "the development level of the technology market" and "the government's emphasis on science and technology".Other variables are consistent with those set at Equation (1).

3.2 Variable

3.2.1 Independent variable

The independent variable studied in this paper is the level of collaborative development among industry, academia and research institutions, and the coupling coordination degree of industry, academia and research institutions is taken as the specific quantitative measurement index. Therefore, the entropy weight - coupling coordination model is constructed.

It is known that the main bodies of the collaboration among industry, academia and research are the three subsystems of enterprises, universities and research institutions. Therefore, in the first step of this paper, the index systems of the three subsystems of enterprises, universities and research institutions are respectively constructed. Referring to the research of relevant scholars including Shao Hanhua (2022) et al., a series of variables that have an impact on the three subsystems were selected:

Table 1 The index systems of the three subsystems of industry-university-research cooperation

Enterprise dimension	university dimension	research institution dimension
Internal expenditure on R&D funds	Internal expenditure on R&D funds	Internal expenditure on R&D funds
Full-time equivalent of R&D personnel	The number of patent applications	The number of patent applications
Sales revenue of new products	The number of scientific and technological papers published	The number of scientific and technological papers published
Funds for new product development	Full-time equivalent of R&D personnel	Full-time equivalent of R&D personnel
The number of patent applications	The number of R&D projects	The number of R&D projects
The number of R&D projects	The number of R&D projects	The number of R&D projects

Considering that the data volume in the index system selected in this study is large and the data structure is complex, therefore, the entropy weight method was adopted for data processing in the second step of this study. The coupling coordination degree is calculated by comprehensively applying the coupling degree model and the coordination degree model. A single consideration cannot fully reflect the true relationship between subsystems. The coupling degree can reflect the relationship and degree of mutual influence between subsystems. The higher the degree, the more intense the influence (Tian Litao and Wang Shaojian, 2022). This paper refers to the research on the calculation of coupling coordination degree by Song Min (2023), Wen Xianming (2019), etc., and calculates the coupling coordination degree of the three subsystems of enterprises, universities and research institutions, such as Equations (10) and (11) :

$$C = 3\sqrt[3]{(u_1 \times u_2 \times u_3) / \prod(u_1 + u_2 + u_3)} \quad (5)$$

$$D = \sqrt{C \times T}, T = \alpha f(x) + \beta g(x) + \gamma h(z) \quad (6)$$

Among them, C represents the coupling degree, D represents the coupling coordination degree of the three subsystems of industry-university-research collaboration, and T represents the coordination index of industry-university-research collaboration. μ_1、μ_2、μ_3 respectively represent the three subsystems of enterprises, universities and research institutions.

3.2.2 Dependent variable

The dependent variable studied in this paper is the level of economic development, and per capita gross domestic product is taken as the quantitative indicator. However, since the price level is changing with the increase of years, directly using nominal per capita GDP may lead to incorrect empirical results. Therefore, when dealing with the per capita GDP data in this paper, the actual per capita GDP is adopted as the final measurement standard. Specifically, in this paper, the first year of the time series (2009) is selected as the base year. Based on the price level of this year, the per capita GDP of subsequent years is converted and adjusted. The conversion is based on the per capita GDP index published in each year. This index takes the base year as 100 and reflects the relative changes in actual economic growth in different years. By combining the per capita GDP value of the base year with the per capita GDP index of each year and eliminating the influence of changes in the price level, the actual per capita GDP data of each region at comparable prices can be obtained. The advantage of this approach lies in that it can more accurately reflect the level of economic development under the circumstances of price changes.

3.2.3 Control variable

In order to enhance the credibility and robustness of the model in this paper and control other factors that may affect the level of economic growth, the following six control variables are introduced in this paper: industrial structure, urbanization level, scale of fiscal expenditure, degree of foreign trade, population density and consumption capacity. The introduction of these variables all referred to the analysis of the existing literature in the academic circle. For example, the optimization and upgrading of the industrial structure have a significant impact on economic growth. The rationalization and sophistication of the industrial structure have obvious and differentiated effects on economic fluctuations (Gan Chunhui et al., 2011). Hou Lizheng (2019) pointed out when studying the industrial structure adjustment in Tianjin that the proportion of the tertiary industry has been increasing year by year and has gradually become an important driving force for economic development. The increase in the proportion of the tertiary industry is usually closely related to the transformation of the economic development stage and can significantly promote the improvement of the quality and efficiency of economic growth. Therefore, in this paper, by calculating the proportion of the added value of the tertiary industry to that of the secondary industry, the control variable of industrial structure (Tivv) is introduced.

3.2.4 Adjusting variable

This study takes "the development level of the technology market" and "the government's emphasis on science and technology" as moderating variables, and respectively selects the ratio of the transaction volume of the technology market to GDP and the ratio of fiscal science and technology expenditure to fiscal expenditure as their measurement indicators. Among them, the development level of the technology market measures the activity of the transformation of scientific and technological achievements within the region. In this paper, "the ratio of the transaction volume of the technology market to the regional GDP" is adopted as a quantitative indicator. This indicator can directly reflect the degree of marketization of scientific and technological achievements from the laboratory to industrialization, thereby demonstrating the development level of the technology market. Another indicator, "the ratio of fiscal expenditure on science and technology to fiscal expenditure", reflects the government's financial investment and financial support in science and technology, which directly indicates the government's emphasis on science and technology. By setting two moderating variables, this paper can further analyze their moderating roles in the collaboration among industry, academia and research institutions and the mechanism and path of economic growth, providing empirical basis for expanding the research boundary.

3.3 Data

This paper selects panel data covering 30 provinces in China from 2009 to 2022 for empirical analysis. All the data are from the "China Macroeconomic Database". Firstly, the data of 30 provinces were used because Hong Kong, Macao, Taiwan and the Tibet region were excluded from the domestic provinces. This can not only avoid the differences in statistical standards caused by the "one country, two systems" system, but also prevent the impact of data shortage in these regions due to objective reasons. Secondly, the time series data started from 2009, which was to avoid the impact of the 2008 financial crisis and the interference of short-term sharp fluctuations. Meanwhile, since 2009, China's economy has entered a relatively stable stage of recovery and development with a gentle trend. Taking this as a starting point, it is possible to more accurately explore the long-term impact of the coordinated development of industry, academia and research on economic growth.

Table 2 Descriptive statistical results

Variable	Obs	Mean	Std. Dev.	Min	Max
Ccd	420	0.275	0.142	0.028	0 .720
Gdpp	420	52171.220	29104.930	10309.000	165272.200
Pd	420	471.068	701.852	7.711	3950.794
Empe	420	0.270	0.300	0.008	1.548

Cge	420	0.243	0.101	0 .096	0.643
Ur	420	58.820	12.724	29.890	89.600
Tivv	420	1.214	0.704	0 .500	5.297
Trsc	420	0.375	0.066	0.183	0.603

4. Analysis of Empirical Results

In this study, in order to explore the influence mechanism and action path of the degree of coordinated development of industry, academia and research on the level of China's economic growth, an entropy weight-coupling coordination model was constructed. To ensure the fitting effect and accuracy of the model, a series of operations were carried out successively in this study: including considering the influence of control variables, dividing samples from the eastern, western and central regions for heterogeneity analysis, introducing relevant interaction terms to support the moderating effect, conducting robustness tests, and logarithmic processing of the data. The results of the regression model are as follows.

4.1 Benchmark result

The regression results of the benchmark model are shown in Table (1) below. The core explanatory variable of this study, the degree of coordinated development of industry, academia and research (Ccd), showed significant positive effects in all four models (the regression coefficients were 0.190, 0.316, 0.119 and 0.109 respectively, and the maximum t value reached 9.41), all being significant at the 1% significance level, which is consistent with the expectations of this paper. It indicates that the promoting effect of Ccd on Gdpp is significant and stable. It is evident that the coordinated development of industry, academia and research, as an important component of the national innovation system, plays a significant role in promoting high-quality economic growth in China. By strengthening the cooperation among universities, research institutions and enterprises, not only has the efficient flow of knowledge and technology been achieved, but also the transformation efficiency of scientific and technological achievements and the technological innovation ability of enterprises have been enhanced. Studies show that this collaborative mechanism also helps to enhance the total factor productivity of enterprises, especially in technology-intensive industries (Wang et al., 2023). Therefore, the coordinated development of industry, academia and research is not only a key path for technological progress, but also an important strategic support for promoting long-term sustainable economic growth.

Among them, a series of control variables were successively introduced in the four models. While improving the accuracy, the influence models were enriched and optimized, and various possibilities of the action paths were explained. Firstly, in the three models, the coefficient of Pd has always been significantly negative, which has a stable inhibitory effect on Gdpp, indicating that when the population density is too high, it will impose a burden on economic development. Then it can be seen that there is a stable positive correlation between Empe and Gdpp, which undoubtedly reflects the driving effect of foreign trade on economic growth. However, Cge has a negative impact on Gdpp. Combined with relevant studies, it can be speculated that this might be due to excessive fiscal expenditure causing market fluctuations instead, resulting in the failure to effectively translate into economic benefits. Then, the coefficient of Ur is as high as 0.58, reflecting its significant promoting effect on Gdpp, indicating that the higher the urbanization rate, the more it can drive economic growth. The relationship between Tivv and Gdpp is significantly negatively correlated, indicating that an improper industrial structure hinders economic development to a certain extent. Finally, Trsc positively incentivizes Gdpp, demonstrating the significant driving role of consumption in economic growth.

Table 3 Benchmark results of the impact of industry-university-research collaboration on economic growth

	Gdpp	Gdpp	Gdpp	Gdpp
Ccd	0.190*** (6.26)	0.316*** (9.41)	0.119*** (4.74)	0.109*** (4.24)
Pd		-0.535*** (-6.47)	-0.418*** (-7.06)	-0.435*** (-7.30)
Empe		0.039*** (4.16)	0.030*** (4.65)	0.031*** (4.78)
Cge			-0.200*** (-10.88)	-0.184*** (-9.04)
Ur			0.580*** (14.34)	0.565*** (13.70)
Tivv				-0.038** (-2.24)
Trsc				0.028 (1.33)
Constant term	10.497*** (186.93)	13.703*** (28.35)	10.114*** (24.39)	10.299*** (24.46)
Time effect	Yes	Yes	Yes	Yes
Regional effect	Yes	Yes	Yes	Yes
R2	0.9777	0.9812	0.9911	0.9913
Sample size	420	420	420	420

Note: *, **, and *** respectively indicate significance at the 10%, 5%, and 1% significance levels, and the values in parentheses are the corresponding t-statistics

4.2 Heterogeneity Analysis

Given the vast territory of our country, there are significant differences among various regions in terms of natural resources, economic foundations, and policy support. For a long time, regional development has shown a pattern of being stronger in the east and weaker in the west, with the central region taking over. Relying on the coastal advantages and the pioneering conditions of opening up to the outside world, the eastern region has achieved relatively fast economic growth and a relatively complete industrial structure. The central region has benefited significantly from the gradient transfer of industries in recent years, and its development momentum has strengthened. However, the western region is constrained by geographical conditions and infrastructure, and its overall development level lags behind relatively. Against this background, in the empirical analysis of this paper, the samples are divided into three categories: the east, the middle and the west, to explore whether there are significant differences in the impact of the core explanatory variables of this paper on the economy in different regions, so as to make the results more targeted and accurate.

The results are shown in Table (2). The regression coefficient of the core explanatory variable Ccd in the central region is 0.687, which is significantly positive and highly significant at the 1% level (t=8.29), indicating that in the central region, this variable has a significant promoting effect on economic growth. In the eastern region, the coefficient of Ccd is 0.108, which is significant at the 5% significance level (t=2.37), indicating that its influence is weaker compared to the central region, but it still has a certain promoting effect. In the western region, the coefficient of Ccd is 0.001 and not significant, indicating that its effect can almost be ignored. The reasons for the results of regional heterogeneity mainly stem from the fundamental differences among various regions in terms of economic development stage, resource allocation capacity and institutional implementation environment. The eastern region, with its early opening up and continuous capital accumulation, has formed a relatively complete market mechanism and industrial system. The process of its stable and regularized institutional change has a certain positive effect on economic growth (Wang Jun et al., 2015). In contrast, the central region is in the "latecomer catch-up" stage. The industrial structure is constantly optimized, and the infrastructure and institutional environment are continuously improved, which makes the new institutional supply have a more significant promoting effect on its economic growth. Although the western region has resource potential, due to its remote geographical location, weak infrastructure and lagging implementation of systems, it has always been in a backward position in economic development. This structural disparity among regions also confirms the regional development principle of "tailoring measures to local conditions and implementing classified policies" emphasized by the new structural economics (Fu Caihui, 2017). These differences jointly constitute the different response paths and intensities of each region to the core explanatory variables.

From the perspective of other control variables, Pd is negative in both the eastern and western regions, but as high as 0.77 in the central region, reflecting that the large regional differences in population density lead to different impacts on economic growth. However, Cge was negative in all three regions, among which the western region had the greatest impact (with a coefficient of -0.242), indicating that the efficiency or structure of fiscal expenditure still needs to be optimized and has obviously not played an application role in the western region. Ur was significantly positive in the east (with a coefficient of 0.678) and the west (with a coefficient of 0.524), negative and not significant in the central region, or related to the urban expansion pattern and absorption capacity.

Table 4 Heterogeneity analysis results of the impact of industry-university-research collaboration on economic growth

	East	Middle	West
Ccd	0.108** (2.37)	0.687*** (8.29)	0.001 (0.03)
Pd	-0.169 (-1.21)	0.771** (2.24)	-0.291*** (-2.92)
Empe	0.017 (0.54)	0.013 (0.69)	0.034*** (4.85)
Cge	-0.183 (-4.39)	-0.112 (-1.65)	-0.242*** (-8.00)
Ur	0.678*** (7.25)	-0.358 (-1.47)	0.524*** (5.76)
Tivv	-0.113** (-2.63)	0.041 (0.89)	-0.001 (-0.01)
Trsc	-0.018 (-0.44)	-0.063 (-0.89)	0.082*** (3.19)
Constant term	8.733*** (7.43)	7.709*** (4.03)	9.021*** (17.39)
Time effect	Yes	Yes	Yes
Regional effect	Yes	Yes	Yes
R2	0.9892	0.9962	0.9958
Sample size	154	84	154

Note: *, **, and *** respectively indicate significance at the 10%, 5%, and 1% significance levels, and the values in parentheses are the corresponding t-statistics

4.3 Analysis of moderating effect

In order to further reveal the mechanism by which the degree of coordinated development of industry, academia and research (Ccd) affects the level of China's economic development (Gdpp), this paper introduces an interaction term to examine whether the level of development of the technology market (Tvg) and the government's emphasis on science and technology (Stf) play a moderating role in this relationship.

The results are shown in Table (3). According to the results of the regression analysis, the coefficient of the interaction term (Ccd*Tvg) clearly shows a significant positive effect (0.013), which indicates that the development degree of the technology market plays a key role in promoting the transformation of innovation achievements among industry, academia and research into actual economic benefits. In other words, the technology market provides an efficient circulation and connection platform for the implementation of industry-university-research achievements, thereby strengthening the positive promotion of economic output by industry-university-research collaboration. The coefficient of another interaction term, Ccd and Stf (Ccd*Stf), is 0.034, which is also significantly positive at the 1% level. This reflects that the government's investment attention and policy guidance in science and technology can significantly enhance the economic effect of the coordinated development of industry, academia and research. This undoubtedly indicates that in an environment with strong support from science and technology policies, information communication, resource allocation and technology transfer among industry, academia and research institutions are smoother and more efficient, which is conducive to improving the allocation efficiency and output level of innovation elements.

Furthermore, both Tvg and Stf, as moderating variables, are themselves significantly positive and have a significant positive promoting effect on Gdpp in both models. This further confirms precisely that a favorable technological market environment and institutional environment, while promoting economic development, can also provide favorable external conditions for the collaboration among industry, academia and research in itself.

Therefore, the above analysis of the moderating effect indicates that the impact of the coordination among industry, academia and research on economic performance is constrained by external environmental conditions, especially the development level of the technology market and the government's emphasis on science and technology. This enriches the research content of this article and provides policy implications for achieving high-quality economic development in China.

Table 5 Results of the moderating effect of industry-university-research collaboration on economic growth

	Gdpp	Gdpp	Gdpp	Gdpp
Ccd	0.108*** (4.22)	0.211*** (5.99)	0.078*** (3.01)	0.254*** (4.78)
Ccd*Tvg		0.013*** (4.16)		
Ccd*Stf				0.034*** (3.78)
Tvg	-0.001 (-0.09)	0.020*** (3.47)		
Stf			0.036*** (4.67)	0.077*** (5.83)
Pd	-0.434*** (-7.20)	-0.482*** (-8.02)	-0.437*** (-7.53)	-0.515*** (-8.49)

Empe	0.031*** (4.65)	0.029*** (4.42)	0.023*** (3.56)	0.023*** (3.55)
Cge	-0.183*** (-8.76)	-0.182*** (-8.88)	-0.170*** (-8.51)	-0.174*** (-8.86)
Ur	0.566*** (13.36)	0.589*** (14.09)	0.540*** (13.34)	0.586*** (14.09)
Tivv	-0.038** (-2.23)	-0.042** (-2.55)	-0.33** (-2.02)	-0.32* (-1.95)
Trsc	0.028 (1.33)	0.023 (1.09)	0.019 (0.92)	0.012 (0.58)
Constant term	10.291***	10.621***	10.498***	10.960***
Time effect	Yes	Yes	Yes	Yes
Regional effect	Yes	Yes	Yes	Yes
R2	0.9913	0.9917	0.9918	0.9921
Sample size	420	420	420	420

Note: *, **, and *** respectively indicate significance at the 10%, 5%, and 1% significance levels, and the values in parentheses are the corresponding t-statistics

4.4 Robustness analysis

To further verify the reliability of the benchmark regression results, this paper adopts different methods to conduct robustness tests, mainly including two types of methods: changing samples and dealing with potential endogeneity problems.

Firstly, in terms of the operation of the samples, this paper successively eliminated four municipalities directly under the Central Government (Beijing, Shanghai, Tianjin, and Chongqing) to avoid the interference of their particularities in resource allocation, policy support, etc. on the overall results. Meanwhile, considering the significant impact of the epidemic on China's economic operation, the observed values from 2020 and beyond were excluded, and only the samples of relatively stable years were retained for regression analysis. The results show that under different sub-samples, the core explanatory variable, the coupling coordination degree of industry, academia and research (Ccd), still maintains a significant positive influence. The regression coefficient is stable between 0.085 and 0.134, and is significantly positive at the significance level of 1%. This indicates that the research conclusion does not rely on a specific sample structure and has good scalability.

Furthermore, to alleviate the possible endogeneity problem, this paper further adopts the two-stage least square method for estimation. The regression results still show that the impact of Ccd on the economy is positive and significant. Meanwhile, the statistics of the Cragg-Donald test in the first stage are 388.724. The results show that the specific model constructed in this paper has strong explanatory power and the regression results are robust.

In conclusion, the robustness test has double-verified the benchmark results from two perspectives, both supporting that the coordinated development of industry, academia and research has a stable positive effect on China's economic growth, further enhancing the reliability and persuasiveness of the empirical analysis in this paper.

Table 6 the robustness test results of the impact of industry-university-research collaboration on economic growth

	Gdpp	Gdpp	Gdpp
Ccd	0.085*** (3.45)	0.134*** (2.76)	0.112*** (3.84)

Pd	-0.325*** (-5.28)	-0.364*** (-5.20)	-0.519*** (-6.80)
Empe	0.024*** (4.03)	0.024*** (4.08)	0.026*** (3.19)
Cge	-0.177*** (-9.36)	-0.178*** (-9.87)	-0.185*** (-7.11)
Ur	0.569*** (14.04)	0.537*** (10.77)	0.612*** (11.84)
Tivv	-0.029* (-1.86)	-0.021 (-1.23)	-0.053** (-2.54)
Trsc	0.028 (1.47)	0.023 (1.03)	-0.055* (-1.88)
Constant term	9.729***	11.139***	10.483***
Time effect	Yes	Yes	Yes
Regional effect	Yes	Yes	Yes
Cragg-D F		388.724	
R2	0.9915	0.9975	0.9893
Sample size	390	390	330

Note: *, **, and *** respectively indicate significance at the 10%, 5%, and 1% significance levels, and the values in parentheses are the corresponding t-statistics

5. Conclusions and Suggestions

This paper takes the impact of the coordinated development of industry, academia and research on China's economic growth as the entry point, and studies its action path and influence mechanism from both theoretical and empirical levels. Based on the panel data of 30 provinces across the country from 2009 to 2022, an empirical analysis was conducted using the entropy weight-coupling coordination model. Research has found that the coordinated development of industry, academia and research has significantly promoted China's economic growth. Specifically, in-depth cooperation among the industrial sector, universities and research institutions has not only enhanced the efficiency of technology transformation, but also strengthened the innovation capabilities of enterprises and promoted the upgrading of the industrial structure. Further analysis shows that the development level of the technology market and the government's emphasis on science and technology have a significant positive moderating effect on the economic promotion effect of the collaboration among industry, academia and research. From a regional perspective, the effect of coordinated development is most prominent in the central region, followed by the eastern region, while the role in the western region is not obvious. This indicates that differences in regional foundations, resource conditions, and institutional environments have affected the implementation effect of the industry-university-research collaboration model.

To further leverage the positive role of the coordinated development of industry, academia and research, and promote high-quality and sustainable economic growth, the following suggestions are put forward:

Firstly, it is suggested that the government enhance its guidance and support for the collaboration among industry, academia and research institutions. This can be achieved by improving the policy system, increasing investment in scientific and technological innovation, and introducing tax incentives and other incentive measures to promote in-depth cooperation among enterprises, universities and research institutes. At the same time, a supervision and performance evaluation mechanism should be established and improved to ensure the efficient use of fiscal funds.

Secondly, it is necessary to improve the construction of the technology market, strengthen the protection of technology property rights and the construction of trading platforms, actively guide scientific and technological achievements to precisely match with the demands of enterprises, and promote the transformation of innovation achievements into real productive forces.

Finally, targeted policies should be formulated based on regional differences. The central region should accelerate the optimization and upgrading of the industrial structure, undertake the industrial transfer from the eastern region, and cultivate emerging industries. The eastern region should continue to strengthen innovation-driven development, enhance the capacity for the transformation of scientific and technological achievements and the level of the industrial chain. The western region needs to focus on strengthening infrastructure and talent team building, optimizing the innovation environment, and stimulating regional development potential.

In conclusion, promoting the coordinated development of industry, academia and research can help enhance the quality and resilience of economic growth and is also an important way for China to maintain its competitive edge in a complex international environment. In the future, it is necessary to continuously improve the linkage mechanism among industry, academia and research, optimize the allocation of innovation resources, and implement differentiated support policies based on regional characteristics to ensure that collaborative innovation truly takes root and yields results, providing solid support for China's economy to achieve high-quality development and the goal of innovation-driven growth.

In conclusion, promoting the coordinated development of industry, academia and research not only helps to enhance the quality and resilience of economic growth, but also provides a path for China to maintain its competitive edge in the current complex and volatile international environment. Throughout the entire process from theoretical analysis to empirical research in this article, it is clearly demonstrated that the deep integration and coordinated development of industry, academia and research can significantly promote the high-quality growth of China's economy. In particular, the research further verified that the maturity of the technology market and the scale and policy orientation of the government's investment in science and technology have a significant positive moderating effect on the synergy among industry, academia and research. The issue of regional development differences reflected in the empirical research of this paper is particularly worthy of attention: The differences in basic conditions, innovation ecological environment and policy implementation capabilities among various regions determine that the collaborative model cannot be "one-size-fits-all", but differentiated support policies should be precisely implemented. In the future, the government needs to continue to explore in depth in areas such as the linkage mechanism among industry, academia and research, the environment for the transformation of technological achievements, the allocation of innovation resources, and regional customized policies, gradually optimize the relevant mechanisms and institutional systems, and ensure that the effectiveness of the coordinated development of industry, academia and research can truly be implemented and produce practical results. Only in this way can the collaborative innovation among industry, academia and research institutions continue to play a role and contribute to the full realization of the national economic modernization and innovation-driven strategic goals.

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