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УПРАВЛЕНИЕ ИНТЕГРАЦИЕЙ НАУКИ И ПРОИЗВОДСТВА: СУЩНОСТЬ, ПРЕДПОСЫЛКИ И ОСНОВНЫЕ ТЕНДЕНЦИИ

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Аннотация. Эффективная интеграция науки и промышленности играет ключевую роль в формировании инновационно ориентированной экономики, стимулируя технологические прорывы и обеспечивая устойчивый рост. Оценка факторов, влияющих на эту интеграцию, имеет существенное значение для принятия политических и стратегических решений. Данное исследование основано на анализе панельных данных 31 провинции Китая за период 2011–2022 гг. С помощью модели взвешивания энтропии и модели сопряженной координации проведена комплексная оценка уровня интеграции науки и промышленности в Китае. Двухфакторная панельная квантильная модель с фиксированными эффектами также позволила выявить влияние различных факторов, включая входящие и исходящие прямые иностранные инвестиции, протяженность общественного транспорта, уровень медицинского и санитарного обслуживания, а также темпы урбанизации, на уровень интеграции науки и промышленности. Результаты исследования демонстрируют значительное усиление координации между научной сферой и промышленностью в Китае, особенно в восточных регионах страны. Выявлено, что поступление прямых иностранных инвестиций и развитие общественного транспорта оказывают значительное влияние на улучшение интеграции науки и промышленности, в то время как урбанизация не всегда играет ключевую роль в этом процессе. Кроме того, установлено, что на поздних этапах развития уровень интеграции также начинает зависеть от исходящих иностранных инвестиций, что подчеркивает важность международного сотрудничества в сфере науки и технологий. Полученные выводы имеют значительную практическую ценность и могут быть использованы для разработки стратегий по повышению эффективности взаимодействия науки и промышленности не только в Китае, но и в других странах, заинтересованных в стимулировании инновационного развития. Исследование подчеркивает важность государственного регулирования, международных инвестиций и инфраструктурного развития в процессе формирования высокотехнологичной и конкурентоспособной экономики.

Ключевые слова: развитие науки; развитие промышленности; комплексное развитие; анализ факторов влияния; инновационная экономика; международные инвестиции; государственная политика.

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THE INTEGRATION MANAGEMENT OF SCIENCE AND INDUSTRY: ESSENCE, BACKGROUNDS AND MAIN TRENDS

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Abstract. The integration of science and industry is crucial for fostering an innovation-driven economy, accelerating technological advancements, and ensuring sustainable growth. Understanding of the factors influencing this integration is essential for strategic decision-making. This study analyses panel data from 31 Chinese provinces in 2011–2022. We employ the entropy-weighted model and the coupling coordination model to comprehensively assess the level of science – industry integration in China. Additionally, a two-way fixed-effects panel quantile model examines the impact of inward and outward foreign direct investment, public transportation infrastructure, healthcare service capacity, and urbanisation rates on integration. The findings indicate a measurable increase in science – industry coordination in China, particularly in the eastern regions, where policy support and investment have driven advancements in technology transfer and innovation capacity. Foreign direct investment and public transportation expansion significantly enhance integration, while urbanisation's influence varies, showing stronger effects in highly industrialised areas. Additionally, outward foreign investment becomes a key driver at later development stages, highlighting the role of international collaboration. These insights provide valuable guidance for developing strategies to strengthen science-industry interactions, not only in China but also in other countries aiming for innovation-driven growth. The research underscores the need for targeted government policies, strategic international investments, and infrastructure expansion to foster deeper science – industry integration, ultimately driving technological progress and economic competitiveness.

Keywords: science development; industry development; integrated development; influencing factors analysis; innovation economy; international investment; government policy.

Introduction

Industry, as the lifeline of economic development, reflects a country's comprehensive national strength. Economic globalisation and the rapid development of science have made the competition faced by countries around the world increasingly fierce. The traditional closed self-development and output innovation management model of industry can no longer meet the current market demand for innovation, and industry must seek external knowledge sources. For this reason, the science and industry integration management model came into being [1]. Because the science and industry integration management can effectively promote the gathering of innovation resources and the transformation of scientific and technological achievements, countries such as the United States, the United Kingdom, Japan, and China have formulated corresponding policies to promote the integration of science and industry, and even regard it as a national innovation strategy [2; 3]. Based on this, the present study first combed the background of science and industry integration management to accurately understand its essence. On this basis, this study also used the entropy value empowerment model to scientifically evaluate the science and industry development level in China and used the coupling coordination model to explore the integration development trend of science and industry in China, in order to contribute to the high-quality integration management of science and industry.

Existing studies mainly use the entropy weighting method, principal component analysis method and factor analysis method to evaluate the level of science development and industry development. For example, some researchers [4; 5] respectively built a 12-item indicator system including three dimensions of science input, science output and science environment and a 10-item indicator system including three dimensions of industry process, industry resources and industry environment, and they used the TOPSIS order relation method and factor analysis methods to measure and evaluate the science development level of Liaoning Province in China from 2012 to 2016 and the industry development level of Xinjiang Province in China in 2014. The principal component analysis method based on the European innovation scoreboard to measure the science development level and industry development level of EU countries from 2012 to 2019 was used by A. Kleszcz. The researcher analysed its influencing factors [6]. The study found that R & D expenditure, institutional support, and information level are important factors affecting science development level [7–9]. Economic development level, human capital and scientific and technological innovation significantly affect industry development level [10; 11].

Most of the existing studies treat science and industry as two independent entities, measuring and analysing their development levels and influencing factors respectively. Few scholars have examined the coordinated development level and influencing factors between science and industry. Industry is an important driving force for promoting economic growth, while science is an important way to achieve the transformation of the economic development model from extensive scale to value-added quality. Strengthening the integrated development of science and industry is of great significance to enhancing innovation potential and promoting high-quality economic development. To this end, this paper takes China as the object, adopts the entropy weighting method and the coupling coordination model to evaluate and measure the development level of science and industry in China and their integrated development trend, and on this basis analyses the factors affecting the integrated development of the two, and proposes countermeasures for the existing problems.

Before the 19th century, science and technology developed relatively independently. With the advent of the Second Industrial Revolution, mankind entered the electrical age. Science was no longer a purely theoretical study, and technological progress needed to be supported by scientific research. At the end of the 19th century, German dye manufacturers took the lead in establishing industrial laboratories and hired professional researchers to conduct research. The establishment of industrial research laboratories combined the generation and application of new knowledge. Subsequently, companies *Kodak*, *General electric*, and *Bell telephone system* in the United States also established their own industrial laboratories [12]. The establishment of industrial research laboratories marked the emphasis on scientific research and technological progress within the industry, which actively promoted the establishment of exchanges and cooperation between industry and universities and research institutes.

The earliest example of cooperation between industry and universities can be traced back to the Terman's innovation management model created by Stanford University in the United States in the 1950s. This model fully utilised the advantages of both parties and created legends such as Silicon Valley and Boston Route 128, which had a wide impact worldwide [13]. Since the 1970s, with the rise of emerging technologies, the integration of science and industry management has become a hot topic in academic research. Scholars have successively proposed concepts such as synergetics theory, national innovation system, and triple helix model, which have important theoretical and practical significance for strengthening the management of science and industry integration. Entering the 21st century, developed countries such as the United States, Germany, and Japan have been enhancing the connection between science and industry, and strengthening the management of science and industry integration has become one of the important policies for countries to maintain their competitiveness and enhance their innovation capabilities [14].

At the beginning of the founding of the People's Republic of China in 1949, the industrial foundation was weak. International technical assistance and returning scientists were the main forces for China's industrial technological progress at that time. During this period, China implemented a highly centralised science and technology management system. The industry mainly undertook production functions, and scientific and technological research and development was the responsibility of research institutes and universities. Under the cooperation of industry management departments, research institutes and universities carried out exchanges and cooperation with industry [15]. After the reform and opening up in 1978, China implemented the development policy of market for technology. Technology introduction and foreign direct investment gradually became the main forces for China's industrial technological progress. During this period, the status of industry as a subject of technological innovation began to stand out, and some large and medium-sized state-owned industries began to employ and train researchers.

In addition, driven by the market operation mechanism, industry actively sought to cooperate with research institutes and universities to improve its own innovation capabilities. As the conditions for independent innovation in China's industry gradually matured, in 2006 the Chinese government made improving independent innovation capabilities a national development strategy. During this period, China's industrial independent research and development capabilities and technology digestion and absorption capabilities continued to improve. China's industry integrated and utilised high-quality scientific and technological innovation resources from around the world through the establishment of overseas research and development centres and reverse acquisitions of overseas high-tech industries to improve its own industrial research and development capabilities [16].

However, it should be noted that with the diversification of innovation management paradigms, although the management form of the integration of science and industry has changed, its essence is always guided by the government. Science and industry explore the infinite possibilities of knowledge through the exchange and sharing of knowledge, and promote the transfer of science and technology to the industrial sector, thereby accelerating the commercialisation of scientific and technological achievements [17; 18]. In this process, science, as the subject of knowledge innovation, provides industry with original theoretical research and professional and technical personnel, and its resource needs are scientific and technological research and development funds and technology application scenarios. As a subject of technological innovation, industry has advantages such as scientific and technological research and development funds, market information, and the creation of technological value. Its resource needs are cutting-edge technological concepts, research results, and professional talents. As the subject of institutional innovation, the government provides policy and environmental guarantees to support the deep integration of science and industry by issuing corresponding policies and building communication and cooperation platforms. When the advantages and needs of science and industry are complementary, industry will gain more profits and further promote industrial upgrading, thereby providing science with more abundant R & D funds and technology application scenarios, better supporting it to explore unknown research fields and break through existing research results, which will in turn have a positive interactive effect on industry development and lay a solid foundation for it to gain more profits (fig. 1).

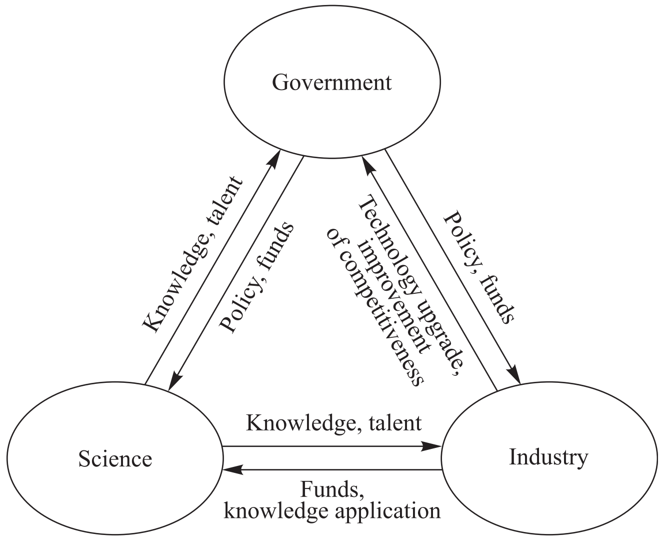

Fig. 1. The logical relations of science, industry and government

Materials and methods

Model building. In order to effectively and comprehensively reflect the development level of science and industry, this study uses the entropy value weighting method to integrate the single indicators of science and industry, and makes an objective and comprehensive evaluation of the development level of science and industry through linear weighted summation. The specific models are built as follows.

The first step is to use the deviation standardisation method to standardise each original indicator:

$$y_{\text{Science}_{i,j}} = \frac{x_{\text{Science}_{i,j}} - \min\left(x_{\text{Science}_j}\right)}{\max\left(x_{\text{Science}_j}\right) - \min\left(x_{\text{Science}_j}\right)} \cdot 0.999 + 0.001,$$

$$y_{\text{Industry}_{i,j}} = \frac{x_{\text{Industry}_{i,j}} - \min\left(x_{\text{Industry}_j}\right)}{\max\left(x_{\text{Industry}_j}\right) - \min\left(x_{\text{Industry}_j}\right)} \cdot 0.999 + 0.001,$$

where $y_{\text{Science}_{i,j}}$ and $x_{\text{Science}_{i,j}}$ represent the j^{th} original indicator of the science development level of province i after and without standardisation respectively; $y_{\text{Industry}_{i,j}}$ and $x_{\text{Industry}_{i,j}}$ represent the j^{th} original indicator of the industry development level of province i after and without standardisation respectively; $\max\left(x_{\text{Science}_j}\right)$ and $\min\left(x_{\text{Science}_j}\right)$ represent the maximum and minimum values of the j^{th} indicator of the science development level respectively; $\max\left(x_{\text{Industry}_j}\right)$ and $\min\left(x_{\text{Industry}_j}\right)$ represent the maximum and minimum values of the j^{th} indicator of the industry development level respectively.

The second step is to calculate the entropy value of each indicator:

$$H_{\text{Science}_j} = -\frac{1}{\ln(n)} \sum_{i=1}^{n} p_{\text{Science}_{i,j}} \ln p_{\text{Science}_{i,j}},$$

$$H_{\text{Industry}_j} = -\frac{1}{\ln(n)} \sum_{i=1}^{n} p_{\text{Industry}_{i,j}} \ln p_{\text{Industry}_{i,j}},$$

where H_{Science_j} represents the entropy value of the j^{th} indicator in the science development evaluation indicator system; H_{Industry_j} represents the entropy value of the j^{th} indicator in the industry development evaluation indicator system; $p_{\text{Science}_{i,j}} = \dfrac{y_{\text{Science}_{i,j}}}{\sum_{l=1}^{n} y_{\text{Science}_{i,j}}}$ and $p_{\text{Industry}_{i,j}} = \dfrac{y_{\text{Industry}_{i,j}}}{\sum_{l=1}^{n} y_{\text{Industry}_{i,j}}}$. In addition, when $p_{\text{Science}_{i,j}}$ and $p_{\text{Industry}_{i,j}} = 0$, let $p_{\text{Science}_{i,j}} \ln p_{\text{Science}_{i,j}}$ and $p_{\text{Industry}_{i,j}} \ln p_{\text{Industry}_{i,j}} = 0$, thereby ensuring that the values of H_{Science_j} and H_{Industry_j} are between 0 and 1.

The third step is to calculate the weight of each indicator:

$$w_{\text{Science}_j} = \frac{1 - H_{\text{Science}_j}}{\sum_{j=1}^{m}\left(1 - H_{\text{Science}_j}\right)} = \frac{1 - H_{\text{Science}_j}}{m - \sum_{j=1}^{m} H_{\text{Science}_j}},$$

$$w_{\text{Industry}_j} = \frac{1 - H_{\text{Industry}_j}}{\sum_{j=1}^{m}\left(1 - H_{\text{Industry}_j}\right)} = \frac{1 - H_{\text{Industry}_j}}{m - \sum_{j=1}^{m} H_{\text{Industry}_j}},$$

where w_{Science_j} represents the weight of the j^{th} indicator in the science development evaluation indicator system; w_{Industry_j} represents the weight of the j^{th} indicator in the industry development evaluation indicator system. The values of w_{Science_j} and w_{Industry_j} are both between 0 and 1, and satisfy $\sum_{j=1}^{m} w_{\text{Science}_j}$ and $\sum_{j=1}^{m} w_{\text{Industry}_j} = 1$.

The fourth step is to calculate the comprehensive score of science development level and industry development level:

$$S_{\text{Science}_i} = \sum_{j=1}^{m} w_{\text{Science}_j} y_{\text{Science}_{i,j}},$$

$$S_{\text{Industry}_i} = \sum_{j=1}^{m} w_{\text{Industry}_j} y_{\text{Industry}_{i,j}},$$

where the larger the values of S_{Science_i} and S_{Industry_i}, the higher the science development level and industry development level of province i.

The fifth step is to establish a coupling coordination model based on the evaluation results of the development level of science and industry and the coupling concept in physics to measure the integration development level of science and industry:

$$D_{i,t} = \sqrt{C_{i,t} T_{i,t}},$$

$$C_{i,t} = \left(S_{\text{Science}_{i,t}} S_{\text{Industry}_{i,t}}\right) / \left[\frac{S_{\text{Science}_{i,t}} + S_{\text{Industry}_{i,t}}}{2}\right]^2,$$

$$T_{i,t} = w_1 S_{\text{Science}_{i,t}} + w_2 S_{\text{Industry}_{i,t}},$$

where $S_{\text{Science}_{i,t}}$ and $S_{\text{Industry}_{i,t}}$ represent the development level of science and the development level of industry of province i in period t respectively; $C_{i,t}$, $T_{i,t}$ and $D_{i,t}$ respectively represent the coordination degree, comprehensive development level and coupling coordination degree between science development level and industry development level of province i in period t. Among them, $D_{i,t}$ reflects the level of integrated development of science and industry. Its value range is 0–1. The larger its value is, the higher the coupling coordination between science and industry, and the higher the level of integrated development between science and industry. Values w_1 and w_2 represent the weights of the two systems, and $w_1 + w_2 = 1$. Since this study considers science and industry to be equally important, both w_1 and w_2 are assigned a value of 0.5.

Indicator selection and weighting. Based on the principles of systematicity, scientificity, representativeness and availability, and referring to existing research [19–22], this study determined a total of 21 indicators for the development level of science and industry. The selected indicator names, impact directions, measurement units and indicator weights are shown in the table 1.

Table 1

Evaluation indicator system for science and industry development

Evaluation object	Indicator names (impact directions)	Measurement units	Indicator weights
Science development	R & D personnel (+)	Person per year	0.093 7
	R & D funding (+)	10 thsd yan	0.102 5
	New product funding (+)	10 thsd yan	0.100 3
	New product sales revenue (+)	10 thsd yan	0.097 9
	Number of invention patent applications accepted (+)	Item	0.004 4
	Number of utility model patent applications accepted (+)	Item	0.091 4
	Number of design patent applications accepted (+)	Item	0.140 5
	Number of invention patent applications granted (+)	Item	0.002 1
	Number of utility model patent applications granted (+)	Item	0.101 6
	Number of design patent applications granted (+)	Item	0.144 8
	Technology market turnover (+)	100 mln yan	0.135 8
Industry development	Number of industrial enterprises (+)	Enterprise	0.226 4
	Industrial added value (+)	100 mln yan	0.170 3
	Total assets of industrial enterprises (+)	100 mln yan	0.144 8
	Total profits of industrial enterprises (+)	100 mln yan	0.118 3
	Return on assets (+)	%	0.009 9
	Asset-liability ratio (–)	%	0.028 4
	Asset liquidity (+)	–	0.027 6
	Inventory turnover rate (+)	%	0.056 4
	Financial reporting complexity (–)	–	0.047 4
	Number of people employed in the secondary industry (+)	10 thsd people	0.170 6

Notes: 1. In the second column sign «+» displays positive contribution of index; sign «–» displays negative contribution of index. 2. In the third column sign «–» displays the absence of measurement unit.

Empirical model building. In order to further analyse the influencing factors of the development level of China's science and industry integration, this study established the empirical analysis model to explore the influencing factors that can effectively improve the development level of China's science and industry integration, in order to provide policy inspiration for government departments.

In terms of variable selection, the explained variable is the integration of science and industry development in China, which is measured by the calculation model set earlier. Based on the reference to existing research [23; 24], this study selected inward foreign direct investment, outward foreign direct investment, length of public buses and trams operation, medical and health service capacity (measured by the ratio of medical and health personnel to the number of medical and health institutions) and urbanisation rate (measured by the ratio of urban population to permanent population) as explanatory variables.

In terms of model setting, in order to evaluate the impact of various explanatory variables on the different distribution positions of China's science and industry integration development level, and to ensure that the evaluation results will not be affected by the extreme values of China's science and industry integration development level, this study chooses to establish the two-way fixed effect panel quantile regression model to evaluate the impact of various explanatory variables on China's science and industry integration development at different distribution levels, and selects representative 25th, 50th, 75th quantiles as the low, medium and high levels of China's science and industry integration development. The specific model settings are as follows:

$$Q_{i,t,\varphi}\left(D_{i,t}\,|\,X_{i,t}\right) = \beta_{0,\varphi} + \beta_{1,\varphi}\mathrm{IFDI}_{i,t} + \beta_{2,\varphi}\mathrm{OFDI}_{i,t} + \beta_{3,\varphi}\mathrm{BUS}_{i,t} + \beta_{4,\varphi}\mathrm{MED}_{i,t} + \beta_{5,\varphi}\mathrm{UR}_{i,t} +$$
$$+ \mathrm{province}_i + \mathrm{year}_t + \mu_{i,t,\varphi},$$

where φ represents the quantile condition; i represents the province; t represents the year; $Q_{i,t,\varphi}\left(D_{i,t}\,|\,X_{i,t}\right)$ represents the development of China's science and industry integration under the φ quantile condition and various explanatory variables; $\beta_{1,\varphi}$, $\beta_{2,\varphi}$, $\beta_{3,\varphi}$, $\beta_{4,\varphi}$ and $\beta_{5,\varphi}$ represent the regression coefficients of each explanatory variable under the φ quantile condition; $IFDI_{i,t}$, $OFDI_{i,t}$, $BUS_{i,t}$, $MED_{i,t}$, and $UR_{i,t}$, represent the inward foreign direct investment, outward direct investment, public buses and trams operating length, medical and health service capacity and urbanisation rate of province *i* in year *t*, respectively; $province_i$ and $year_t$ represent province and year fixed effects respectively; $\beta_{0,\varphi}$ and $\mu_{i,t,\varphi}$ represent the constant term and random interference term under the φ quantile condition, respectively.

Data source and description. The data for evaluating the development level of science and industry of each province in this study are all from the «China Statistical Yearbook» and «China Science and Technology Statistical Yearbook», covering a total of 21 related indicators of science and industry development of 31 provinces (municipalities and autonomous regions) in China from 2011 to 2022. In terms of regional division, this study divides China's 31 provinces (municipalities and autonomous regions) into the eastern region, central region and western region according to the classification indicators of the China National Bureau of Statistics.

Results and discussion

Before deeply analysing the measurement results and influencing factors of the integrated development of science and industry in China, in order to ensure that China's scientific development, industrial development and the integrated development of science and industry are of reference significance to Belarus and can provide policy inspiration for Belarusian government departments, this study first conducted a comparative analysis of the scientific development, industrial development and the integrated development of science and industry in China and Belarus. Based on the availability of data, this study selected the number of R & D organisations and R & D expenditures as evaluation indicators of scientific development, and selected industrial output value and the number of industrial organisations as evaluation indicators of industrial development. The research time was set to 2019–2022, and the measurement method was consistent with the calculating model in the method and methodology, that is, the entropy value weighting model and the coupling coordination model. The measurement results are shown in table 2.

Table 2

Comparison between China and Belarus

Year	China			Belarus		
	Science development index	Industry development index	Integrated development index	Science development index	Industry development index	Integrated development index
2019	0.847 8	0.788 1	0.904 1	0.003 7	0.001 7	0.050 3
2020	0.865 1	0.814 8	0.916 3	0.002 1	0.001 2	0.039 3
2021	0.927 9	0.963 6	0.972 4	0.001 0	0.002 1	0.038 0
2022	0.938 9	1.0	0.984 4	0.001 6	0.002 6	0.044 9

The results show that compared with Belarus, China's scientific development level, industry development level and the integration development of science and industry are all ahead of Belarus, which means that studying the integration development of science and industry in China has positive practical reference significance and theoretical policy implications for Belarus. Therefore, this study will further analyse the measurement results and influencing factors of the integration development of science and industry in China.

The measurement results of the integrated development level of science and industry in China show that from a national perspective, the integrated development level of science and industry in China has been on an upward trend from 2011 to 2022, and the coupling coordination degree between the two has also increased from 0.298 8 to 0.411 2 during this period, an increase of 37.62 %, with an average annual growth of 2.95 %. Among them, 2020 and 2021 are the two years with the fastest growth rate during the observation period, with an increase of 4.54 and 5.57 % respectively (all this data is in the table 3 and fig. 2). This may be related to the decision-making and deployment of improving the system and mechanism of scientific and technological innovation made by the 4th plenary session of the 19th Central Committee held at the end of 2019. This decision has clarified the direction for China's scientific and technological innovation work in the future. However, it should be noted that the integrated development level between science and industry in China is still on the verge of disharmony as a whole, and there is a lot of space for improvement.

Table 3

Measurement results of the integrated development level of science and industry in China

Year	Nationwide	Eastern region	Central region	Western region
2011	0.298 8	0.395 1	0.290 4	0.216 2
2012	0.311 5	0.413 6	0.304 0	0.222 9
2013	0.321 6	0.427 7	0.313 4	0.229 7
2014	0.326 2	0.431 7	0.319 0	0.234 2
2015	0.333 5	0.441 7	0.326 1	0.239 3
2016	0.342 2	0.452 6	0.337 4	0.244 1
2017	0.348 6	0.459 8	0.345 1	0.249 0
2018	0.359 5	0.476 5	0.354 4	0.255 8
2019	0.367 6	0.485 9	0.366 1	0.260 2
2020	0.384 3	0.511 5	0.379 9	0.270 6
2021	0.405 7	0.539 8	0.401 4	0.285 7
2022	0.411 2	0.546 3	0.407 6	0.289 8

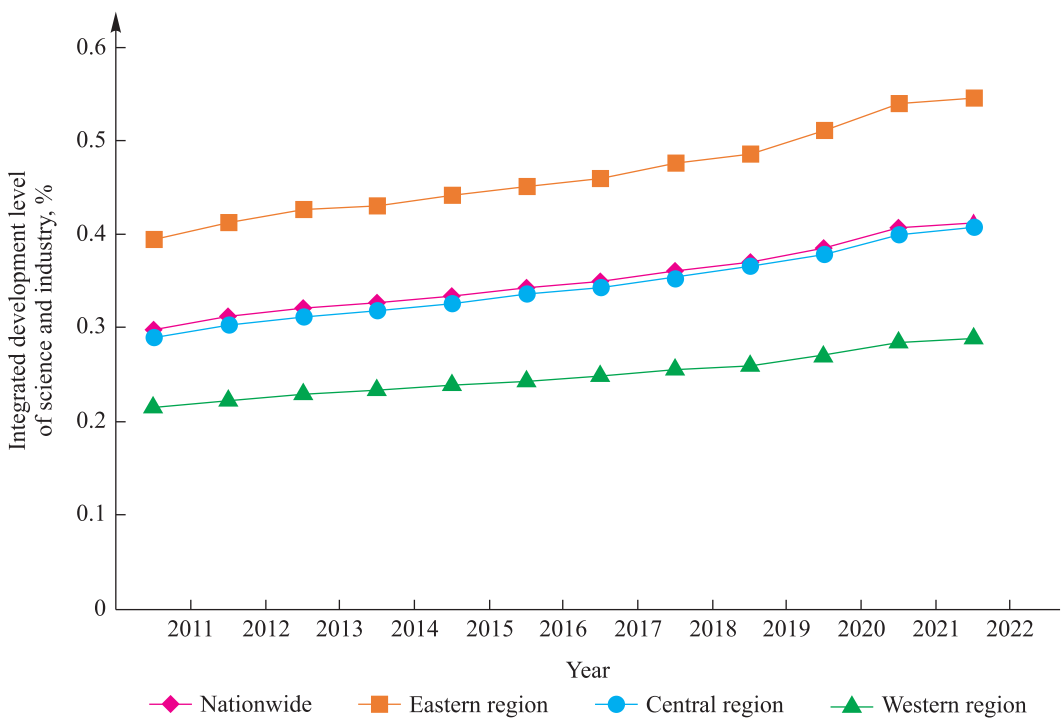

Fig. 2. Trends in the integrated development level of science and industry in China

From a regional perspective, the integrated development level of science and industry varies greatly among different regions in China. Specifically, the coupling coordination degree between science and industry in the eastern region increased from 0.395 1 in 2011 to 0.546 3 in 2022, an increase of 38.27 %, with an average annual growth of 2.99 %. Overall, it is in a barely coordinated state, and its integrated development level has always been higher than that of the national, central and western regions during the observation period. This is probably because the eastern region is the most economically developed region in China. Benefiting from its own geographical advantages, advantages in the concentration of innovative resources and policy advantages, its integrated development level of science and industry can reach a coordinated state.

The coupling coordination degree between science and industry in the central region increased from 0.290 4 in 2011 to 0.407 6 in 2022, an increase of 40.36 %, with an average annual growth of 3.13 %. Although the integrated development level of science and industry in the central region is on par with the national average, its growth rate is ahead of the national level, the eastern region and the western region. This shows that science and industry in the central region are actively establishing a cooperative relationship. For example, Jiangxi Province took the lead in issuing a provincial-level document in the country in 2012 (the Decision on vigorously promoting collaborative innovation in science and technology) to support the integrated management of science and industry. Subsequently, other provinces in the central region successively issued corresponding documents to support integrated management. The central region attaches importance to the integrated management of science and industry, which is an important reason for the rapid growth of its integrated development level.

The coupling coordination degree between science and industry in the western region increased from 0.216 2 in 2011 to 0.289 8 in 2022, an increase of 34.04 %, with an average annual growth of 2.70 %. During the observation period, the integrated development level of science and industry in the western region did not achieve a leap, and has been in a stage of disharmony. Although the economic development level of the western region has been effectively improved since the introduction of the western development policy, the western region is still the weakest region in China's economic development. At the same time, due to the lack of effective communication and cooperation between science and industry, the level and growth rate of integrated development of science and industry in the western region are lower than those in the national, eastern and central regions.

Table 4 reports the analysis of influencing factors of the integration of science and industry in China. The results show that when the development level of integration of science and industry in China is at a low level (25th quantile), inward foreign direct investment, the length of public buses and trams operation, and medical and health service capacity can effectively promote the improvement of China's science and industry integration development level at a significance level of 1 %. Specifically, every 1 % increase in inward foreign direct investment will significantly increase China's science and industry integration development level by 0.020 6 %. Every 1 % increase in the length of public buses and trams operation will significantly increase China's science and industry integration development level by 0.011 4 %. Every 1 % increase in medical and health service capacity will significantly increase China's science and industry integration development level by 0.005 2 %. In terms of promotion, when China's science and industry integration development level is at a low level, inward foreign direct investment is bigger than length of public buses and trams operation that is bigger than medical and health service capacity. However, inward foreign direct investment and urbanisation rate will not have a statistically significant impact on the development level of integration of science and industry in China at this time.

Table 4

Analysis of influencing factors

Variable	Level		
	Low (25th quantile)	Medium (50th quantile)	High (75th quantile)
Inward foreign direct investment	0.020 6*** (0.003 3)	0.016 4*** (0.004 8)	0.012 4*** (0.003 9)
Outward foreign direct investment	0.003 2 (0.005 9)	0.013 6 (0.008 8)	0.016 8** (0.007 2)
Length of public buses and trams operation	0.011 4*** (0.001 1)	0.010 0*** (0.001 6)	0.009 1*** (0.001 3)
Medical and health service capacity	0.005 2*** (0.001 6)	0.007 2*** (0.002 3)	0.006 9*** (0.001 9)
Urbanisation rate	0.007 5 (0.074 4)	– 0.016 5 (0.110 3)	– 0.026 4 (0.089 9)
Constant term	0.150 5** (0.075 2)	0.133 1 (0.111 5)	0.160 7* (0.090 8)
Province-fixed	+	+	+
Year-fixed	+	+	+
R^2	0.880 4	0.885 3	0.911 7
Size of the sample	372	372	372

N o t e s: 1. The sign * indicates $p < 0.1$, the sign ** indicates $p < 0.05$, the sign *** indicates $p < 0.01$. 2. The numbers in brackets are standard errors. 3. Sign «+» indicates the presence of a sign.

When the development level of integration of science and industry in China is at a medium level (50^{th} quantile), inward foreign direct investment, public buses and trams operating length, and medical and health service capacity can effectively promote the improvement of China's science and industry integration development level at a significance level of 1 %. Specifically, every 1 % increase in inward foreign direct investment will significantly increase China's science and industry integration development level by 0.016 4 %. Every 1 % increase in public buses and trams operating length will significantly increase China's science and industry integration development level by 0.010 0 %. Every 1 % increase in medical and health service capacity will significantly increase China's science and industry integration development level by 0.007 2 %. In terms of promotion, when China's science and industry integration development level is at a medium level, inward foreign direct investment is bigger than public buses and trams operating length that is bigger than medical and health service capacity. However, inward foreign direct investment and urbanisation rate will not have a statistically significant impact on China's development level of integration of science and industry at this time.

When the development level of integration of science and industry in China is at a high level (75^{th} quantile), inward foreign direct investment, outward direct investment, public buses and trams operating length, and medical and health service capacity can effectively promote the improvement of China's science and industry integration development level at the significance level of 1; 5; 1; 1 %, respectively. Specifically, every 1 % increase in inward foreign direct investment will significantly increase China's science and industry integration development level by 0.012 4 %. Every 1 % increase in outward direct investment will significantly increase China's science and industry integration development level by 0.016 8 %. Every 1 % increase in public buses and trams operating length will significantly increase China's science and industry integration development level by 0.009 1 %. Every 1 % increase in medical and health service capacity will significantly increase China's science and industry integration development level by 0.006 9 %. In terms of promotion, when China's science and industry integration development level is at a high level, outward direct investment is bigger than inward foreign direct investment that is bigger than public buses and trams operating length that is bigger than medical and health service capacity. However, the urbanisation rate will not have a statistically significant impact on China's science and industry integration development level at this time.

In summary, no matter what the development level of China's integration of science and industry, inward foreign direct investment, the length of public buses and trams operation, and medical and health service capacity can always significantly promote China's science and industry integration development level. But outward foreign direct investment will only have a significant promoting effect on China's science and industry integration development level when the development level is at a high level, and at this time, the promoting effect of outward foreign direct investment is significantly higher than that of inward foreign direct investment, the length of public buses and trams operation, and medical and health service capacity. As for the urbanisation rate, it will not have a statistically significant impact on the development level of China's integration of science and industry.

Conclusions

This study examines the integration of science and industry in China from 2011 to 2022, evaluating its development levels and identifying key influencing factors. The results indicate that while China has made significant progress in strengthening the coordination between science and industry, regional disparities remain evident. The eastern regions demonstrate higher levels of integration due to stronger policy support, investment, and infrastructure, whereas central and western regions experience slower progress. Empirical analysis reveals that inward foreign direct investment, public transportation infrastructure, and healthcare service capacity consistently contribute to improving science – industry integration across all development stages. However, outward foreign direct investment plays a crucial role only when integration reaches a higher level, emphasising the importance of international collaboration in advancing industrial innovation. In contrast, urbanisation does not have a statistically significant impact, suggesting that the expansion of urban areas alone is insufficient to drive deeper science – industry integration without complementary policies and infrastructure development. A comparative analysis between China and Belarus highlights the significant gap in the level of science – industry integration between the two countries. While China has rapidly advanced through strong governmental support, foreign investment, and industrial policies, Belarus still faces structural challenges in fostering effective cooperation between science and industry. The findings suggest that Belarus can benefit from adopting some of China's successful strategies, such as enhancing financial and institutional support for industrial innovation, attracting more foreign investment, and improving the mechanisms for knowledge and technology transfer. Strengthening industry – academia collaboration and ensuring a more innovation-friendly infrastructure could also help Belarus accelerate its integration process. These findings provide valuable insights for policymakers and industry leaders in both China and Belarus. To further enhance science-industry integration, China should adopt region-specific strategies, ensuring that underdeveloped areas receive targeted support. Meanwhile, Belarus can leverage China's experience to formulate policies that strengthen its national innovation system. By addressing these factors, both countries can advance toward a more innovation-driven and sustainable economic model.

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