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Original Paper

An Empirical Study on the Impact of R&D Investment and Industry-University-Research Synergy on Innovation of Chinese Listed Companies

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Abstract

Innovation serves as the core driving force for the sustainable development of enterprises, and the strategic integration of internal R&D and external innovation resources constitutes a critical foundation for enterprises to enhance their innovation capabilities. This study aims to reveal the interactive mechanism between internal R&D investment and external industry-university-research (IUR) cooperation within enterprises, clarify the path through which the synergy between the two affects innovation output, explore the differential performance of various types of enterprises, and provide theoretical and practical references for the optimization of enterprise innovation strategies and policy formulation. Taking Chinese A-share listed companies from 2015 to 2020 as the research sample, this study constructs a multiple linear regression model to analyze the impact of their synergy effect on innovation output, and introduces enterprise scale and property right nature to conduct heterogeneity tests. The empirical results show that the synergy between increased R&D investment and deepened IUR cooperation exerts a significant positive promoting effect on innovation output, and the integration of the two can amplify the marginal benefit of innovation investment. Moreover, this effect exhibits heterogeneity: large-scale enterprises, relying on their resource integration advantages, and state-owned enterprises, by virtue of policy support and resource endowments, have achieved more substantial innovation improvement through the coordinated interaction of the two. The research indicates that internal R&D and external IUR cooperation are the dual core driving forces for enterprise innovation. Enterprises should expand their IUR cooperation networks and establish a sustainable growth mechanism for R&D investment. At the policy level, it is necessary to take into account the heterogeneous characteristics of enterprises, formulate differentiated support policies, and promote the efficient allocation of innovation resources and the optimization of the innovation *ecosystem.*

Keywords

R&D investment, Industry-university-research cooperation, Enterprise innovation, Listed companies, Heterogeneity analysis

1. Introduction

Against the backdrop of complex and volatile international situations and profound reshaping of the global competition pattern, innovation has become a key force driving high-quality global economic development and building core competitiveness. The Report to the 20th National Congress of the Communist Party of China explicitly proposed to "strengthen the dominant role of enterprises in scientific and technological innovation", establishing it as the core path for promoting high-quality development (Deng, Ping, & Zhou, 2025). Facing the new development stage, Chinese enterprises shoulder the important mission of transformation, upgrading, quality improvement and efficiency enhancement. Only by achieving new breakthroughs in improving the quality and effectiveness of scientific and technological innovation can they better support the construction of a modern economic system.

In recent years, Chinese enterprises have achieved remarkable results in the field of scientific and technological innovation. The scale of R&D has continued to expand, the number of patent applications and authorizations has ranked first in the world, and important breakthroughs have been made in some key core technology fields (Wu, 2025). However, it is necessary to soberly recognize that there are still deep-seated structural problems in the current scientific and technological innovation system: insufficient coordination of innovation factors, unsmooth channels for the transformation of scientific and technological achievements into real productive forces, and the overall efficiency of R&D resource allocation needs to be improved (Li & Yuan, 2025; He &Li, 2025). Meanwhile, the transformation of the global technological competition pattern and fluctuations in the international economic and trade environment have also brought new challenges to the stable development of China's scientific and technological innovation ecosystem (Wang, Li, & Zhang, 2022).

In this context, enterprise innovation output, as the most direct micro-measure of innovation efficiency, has become the focus of academic attention. Existing studies mainly explore its driving factors from two paths: internal R&D and external cooperation. The importance of R&D investment as a core indicator of enterprise innovation capability has been widely confirmed: it can not only directly promote the improvement of innovation performance (Sun & Yang, 2025) and drive the development of small and medium-sized industrial enterprises (Yang, Yuan, & Wang, 2025), but also indirectly empower the long-term development of enterprises by strengthening their position in the manufacturing trade network (Zhou, K. G., Lu, Y. Z., & Zhou T, 2025; Zhang, Chen, & Yan, 2024; Liu & Li, 2025), improving profit levels (Wang, Li, & Zhang, 2022; Liu & Qin, 2025), and acting on regional innovation output in synergy with IUR cooperation (Wang, Li, & Zhang, 2022).

On the other hand, IUR cooperation is regarded as a key channel for enterprises to break through internal resource constraints and acquire cutting-edge knowledge. A large number of empirical studies have confirmed that IUR cooperation can significantly promote enterprise technological innovation (Song, Ruan, & Lü, 2025), especially playing a crucial role in promoting breakthroughs in key core technologies (Li & Yuan, 2025; Bai, Yang, & Wang, 2025), cultivating disruptive innovation (Zhang, Chen, & Yan, 2024; Liu & Qin, 2025), and empowering the development of new productive forces (Li & Yuan, 2025; Jing & Jin, 2025), and this conclusion has been supported by empirical evidence from specialized, sophisticated, distinctive and novel listed enterprises (Jing & Jin, 2025). From the perspective of knowledge-based theory, the interaction between IUR cooperation and internal R&D can provide more diversified support for enterprise innovation (Liu & Qin, 2025). In addition, emerging trends such as digital technology-driven development, digital transformation and the integration of digital and real economies have also injected new momentum into enterprise innovation: digital technology can drive the upgrading of enterprise core capabilities (Song, Ruan, & Lü, 2025), the configuration effect of manufacturing enterprise business model innovation and organizational innovation is significant from the perspective of digital transformation (Wang, Zhang, Wang et al., 2024), the integration of digital and real economies directly affects innovation output (Cheng & Zhou, 2023), while supply chain relationship resources and financing constraints indirectly affect enterprise innovation investment (Zhu & Huang, 2022).

Although existing studies have conducted rich discussions on factors such as R&D investment and IUR cooperation, there are still obvious research gaps: First, most studies focus on the independent role of a single factor, and rarely systematically examine the internal mechanism of the synergistic effect of internal R&D investment and external IUR cooperation on enterprise innovation output as the core dimensions of internal and external innovation drivers (Song & Han, 2025; Wang, Zhang, Wang et al., 2024). Second, under the policy background of new productive forces, empirical research on how R&D investment and IUR cooperation synergistically empower enterprise innovation and thus support the development of new productive forces is still relatively scarce (Cheng & Zhou, 2023). Third, no systematic empirical conclusions have been formed on the moderating role of factors such as digital transformation, integration of digital and real economies (Wang, Zhang, Wang et al., 2024; Cheng & Zhou, 2023), supply chain relationships (Zhu & Huang, 2022), and opening-up degree in the process of their collaborative innovation (Wang, Li, & Zhang; Zhu & Huang, 2022). These gaps make it difficult for existing studies to fully reveal the diversified driving mechanisms of enterprise innovation and provide more targeted policy references for practice.

To address the above research deficiencies, this paper uses data from Chinese listed companies between 2015 and 2020 to construct an econometric model. From the collaborative perspective of enterprise internal R&D investment intensity and IUR cooperation density, it deeply analyzes their joint impact and interactive mechanism on enterprise innovation output, aiming to provide evidence-based policy references for optimizing the allocation of enterprise innovation resources and improving the national innovation system.

2. Theoretical Analysis and Research Hypotheses

Enterprise innovation output is not determined by a single factor, but a complex result of the joint action of internal resources and external networks. From the perspective of internal resource base, the Resource-Based View (RBV) points out that an enterprise's unique R&D investment is the fundamental source for it to build and maintain competitive advantages (Sipos, Rideg, Najjar et al., 2025). Continuous and stable R&D investment constitutes the core resource base for enterprises to carry out innovation activities, and profoundly affects the quantity and quality of innovation output through the self-reinforcing mechanism of "input-knowledge precipitation-innovation breakthrough" revealed by the Knowledge Production Function Theory (Social ties and open innovation: impacts on innovation capability, 2025). Meanwhile, from the perspective of external knowledge integration, the Open Innovation Theory emphasizes that enterprises must cross traditional organizational boundaries and systematically integrate and utilize external knowledge resources to promote the innovation process (Social ties and open innovation: impacts on innovation capability, 2025). IUR cooperation is precisely the key path to achieve this goal. It provides enterprises with valuable opportunities to access cutting-edge scientific discoveries and high-level scientific research talents, effectively share R&D risks and accelerate the transformation of achievements through in-depth complementarity and knowledge spillovers.

It is worth noting that internal R&D and external cooperation are not mutually isolated, but have a profound synergistic relationship: a solid internal R&D foundation is a prerequisite for enterprises to effectively absorb and transform external knowledge (i.e., the embodiment of "absorptive capacity"), while active IUR cooperation can break through internal resource bottlenecks and inject new directions and vitality into internal R&D. Based on the theoretical deduction of the above internal and external factors and their synergistic logic, this paper proposes the following core hypothesis:

H: The level of enterprise innovation output is positively affected by both internal R&D investment intensity and external IUR cooperation density; the two jointly drive enterprise innovation by strengthening the internal knowledge base and integrating external heterogeneous knowledge respectively.

3. Research Design

3.1 Data Sources

The empirical analysis data of this study is based on 2,957 Chinese A-share listed companies from 2015 to 2020. The core data source is the China Stock Market & Accounting Research Database

(CSMAR), and the missing variables are supplemented with relevant data from the National Bureau of Statistics. The study matches the enterprise financial data variables, the number of patent applications, the number of professional achievements generated by IUR cooperation and other variables through the unique code of the enterprise, and performs bilateral 1% tail reduction treatment on the variables to eliminate the interference of outliers. Finally, 17,742 valid fiem-year observations for regression analysis are obtained.

3.2 Data Preprocessing

In the data preprocessing step, this paper constructs and defines each basic variable as follows:

Enterprise innovation output (*IO*): Measured by *IO* = ln(1 + total number of enterprise patent applications). Adding 1 before taking the natural logarithm avoids the meaningless logarithmic operation when the number of enterprise patents is zero, and optimizes the distribution form of variables at the same time. Industry-university-research cooperation density (*Coop*): Defined as *Coop* = (Number of patents cooperated by universities and enterprises / Total number of enterprise patents) × 100. The index is expressed in percentage to enhance the horizontal comparability of indicators among different scales. R&D investment intensity (*R&D*): Defined as R&D = R&D investment / total operating income. Enterprise scale (*Size*): Defined as ln(1 + total assets). Government subsidy ratio (Subsidy): Set as $Subsidy_{it}$= government subsidy amount / R&D investment, which is used to measure the relative weight of government subsidies in enterprise R&D investment and intuitively reflect the dependence degree of enterprise innovation activities on government financial support.

The missing values of patent output data are defined as no innovation output of the enterprise in the current period. To control the interference of extreme values on the estimation results, this paper performs bilateral 1% quantile Winsorize treatment on control variables such as *R&D* investment and enterprise scale, which retains data information while reducing heteroscedasticity and parameter estimation bias.

3.3 Variable Definition

The definitions and descriptions of each variable involved in the empirical research are shown in Table 1.

Table 1. Variable Definition Description

Variable Type	Variable Name	Variable Symbol	Measurement Method
Explained Variable	Enterprise Innovation Output	*IO*	Total number of enterprise patent applications
Core Explanatory Variables	R&D Investment Intensity	*R&D*	Ratio of R&D investment to operating income
	Industry-University-Research	*Coop*	(Number of patents

	Cooperation Density		cooperated by universities and enterprises / Total number of enterprise patents) × 100
Control Variables	R&D Personnel Ratio	*R&DPersonRatio*	Proportion of R&D personnel
	Enterprise Scale	*Size*	ln(1 + total assets)
	Government subsidy ratio	*Subsidy*	Government subsidies
	Total Asset-Liability Ratio	*DRL*	Total enterprise liabilities / total assets

3.4 Benchmark Model Setting

To test the impact of internal and external collaborative cooperation between enterprise R&D investment and IUR cooperation on enterprise innovation output, the following regression model is set:

$$IO_{it}=\alpha+\beta_1 R\&D_{it}+\beta_2 Coop_{it}+\gamma X_{it}+\mu_i+\lambda_t+\in_{it}$$

Explanation of relevant variables and parameters of the model:

IO_{it} represents the innovation output of enterprise i in year t;$R\&D_{it}$ represents the R&D investment intensity of enterprise i in year t;$Coop_{it}$ represents the IUR cooperation density of enterprise i in year t;X_{it} is control variable; μ_i is the enterprise fixed effect; λ_t is the year fixed effect; ϵ_{it} is the random effect.

For the panel data used, this study determines the most suitable model form through statistical tests. First, the F-test is conducted to compare the mixed OLS model and the fixed effect model. The test results show that the F statistic is 62.13, which is highly significant at the 1% level (p = 0.001). This result strongly rejects the null hypothesis that "all individual effects are zero", indicating that the fixed effect model is significantly better than the mixed regression model. The Hausman test is used to test whether the random effect model is more effective than the fixed effect model compared with the mixed regression model, that is, whether there is a significant difference between the coefficients obtained by the two methods. The p-value of the Hausman test is 0.000, which strongly rejects the null hypothesis at the 1% significance level. Therefore, the fixed effect model is more suitable for this study sample than the random effect model.

3.5 Descriptive Statistics and Correlation Analysis

Table 2 reports the descriptive statistics of variables related to the regression model. During 2015-2020, there are 17,742 statistical variables of 2,957 Chinese listed companies in the sample. The results show that each company produces an average of two patents per year, of which the average proportion of patents produced in cooperation with universities is 0.8%, and R&D investment accounts for 3.343% of the company's total operating revenue.

Table 2. Descriptive Statistics of Main Variables

Variable Name	Observations	Mean	Std.Dev.	Min	Max
IO	17742	2.000	2.432	0	7.914
R&D	17742	3.343	4.268	0	23.85
Coop	17742	0.008	0.006	0	0.047
Size	17742	3.946	1.500	0.782	8.877
R&DPersonRatio	17742	11.112	13.034	0	63.430
DRL	17742	0.447	0.214	0	0.967
Subsidy	17742	1.010	3.182	0	25.436

To consider whether there is multicollinearity between variables, this paper conducts correlation analysis on the main variables. The results in Table 3 show that enterprise innovation output is significantly positively correlated with R&D investment intensity, which is consistent with theoretical expectations. On this basis, this paper further calculates the variance inflation factor (VIF) to diagnose multicollinearity. The results show that all VIF values are at a low level (the maximum value is 2.26), far lower than the empirical critical value of 5, indicating that the model has no serious multicollinearity problem.

Table 3. Correlation Analysis and VIF Values

	IO	*R&D*	*Coop*	*Size*	*R&DPersonRatio*	*DRL*	*Subsidy*	VIF
IO	1.000							
R&D	0.295^{***}	1.000						2.26
Coop	0.093^{***}	0.035^{***}	1.000					1.000
Size	0.056^{***}	-0.140^{***}	0.012	1.000				1.280
R&DPersonRatio	0.296^{***}	0.740^{***}	0.038^{***}	-0.106^{***}	1.000			2.210

DRL	-0.077***	-0.262***	-0.009	0.465***	-0.227***	1.000		1.350
Subsidy	-0.034***	-0.094***	0.005	0.094***	-0.065***	0.064***	1.000	1.020

Note: * p<0.05, ** p<0.01, *** p<0.001. The same below.

4. Empirical Analysis

4.1 Benchmark Regression Results

According to the benchmark regression model:

$$IO_{it}=\alpha+\beta_1 R\&D_{it}+\beta_2 Coop_{it}+\gamma X_{it}+\mu_i+\lambda_t+\in_{it}$$

The benchmark regression results are reported in Table 4. Column (1) is conducted after controlling for time fixed effects. The estimated coefficients of the core explanatory variables R&D and Coop are both significantly positive at the 1% level. This indicates that the improvement of enterprise R&D investment intensity and IUR cooperation density has a significant promoting effect on enterprise innovation output, thus providing strong empirical support for research hypothesis H.

To further verify the credibility of the results, stricter fixed effects are added in columns (2) and (3). Among them, column (2) adds industry fixed effects to control the changing characteristics of enterprise industries. Column (3) further adds the cross fixed effects of industry and year to control the industry-level characteristics of enterprises changing with years. The inclusion of various fixed effects in the regression model in turn shows that it does not affect the robustness of the conclusion.

4.2 Robustness Tests

4.2.1 Placebo Test

To verify whether the benchmark regression results are affected by omitted variables or model setting bias, this paper conducts a placebo test. We set a dummy treatment variable (placebo_treated), randomly set 20% of the observations in the sample as the "treatment group" and the rest as the "control group", and repeated sampling for 100 regression estimations. Each time, the dummy variable is used to replace the real treatment variable, and the model setting is consistent with the benchmark regression.

The test results show that in 100 simulated regressions, most p-values of the coefficient treatment results of the dummy treatment variable are greater than 0.05. These results indicate that the dummy treatment variable has no obvious systematic impact on the dependent variable, and its coefficient distribution is concentrated near zero. Furthermore, this paper draws the kernel density plot of these estimated coefficients (Figure 1). The results show that it roughly follows a normal distribution centered at zero. Overall, the placebo test results support the robustness of the benchmark regression, indicating that the treatment effect identified above does not stem from accidental factors or model setting bias.

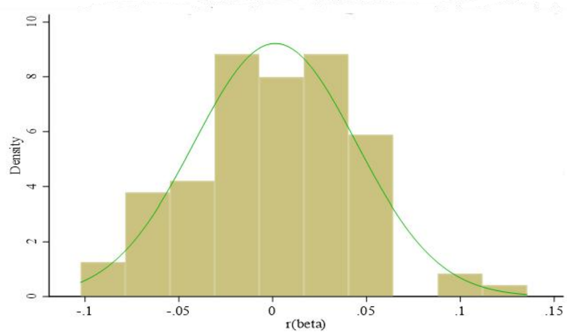

Figure 1. Placebo Test Results

4.2.2 Subsample Regression

To verify the robustness of the benchmark regression results, this paper further conducts subsample analysis. Specifically, this paper divides the overall sample into state-owned and non-state-owned enterprises according to the equity nature of enterprises, and re-estimates the model based on the subsample of state-owned enterprises. Column (4) of Table 4 reports the subsample regression results, in which the coefficient direction and significance level of the core explanatory variables $R\&D_{it}$ and $Coop_{it}$ are consistent with the full sample estimation results (column (2) of Table 4). This finding indicates that the main conclusions of this paper have good robustness among different ownership enterprise groups.

4.2.3 Replacement of Regression Model

To verify the robustness of the benchmark regression results, the study further adopts the Tobit model to replace the high-dimensional linear regression model (reghdfe) to deal with the problem of truncation or corner solution of the dependent variable. It can be seen from column (5) in Table 4 that the coefficient direction and significance of the core explanatory variables $R\&D_{it}$ and $Coop_{it}$ of the Tobit model are consistent with the full sample (column (2) of Table 4), indicating that the main findings of this paper still hold even when considering the data truncation characteristics.

4.2.4 Endogeneity Test

To control the endogeneity bias caused by possible omitted variables and other problems in the model, this paper adopts the instrumental variable method for re-estimation. The study selects the average R&D output of the industry where the enterprise is located as the instrumental variable. This variable is related to the enterprise's own R&D decision, but is unlikely to directly affect its innovation performance through other channels, so it meets the correlation and exogeneity conditions of instrumental variables to a large extent. Column (6) of Table 4 reports the estimation results of the two-stage least squares method (2SLS), showing that the coefficient direction of the core variables is consistent with the benchmark regression results. After controlling the endogeneity interference that may be caused by instrumental variables, the estimation results of the main explanatory variables are still robust, further enhancing the reliability of the conclusions of this study.

Table 4. Benchmark Regression and Robustness Test Results

Explained Variable: IO_{it}	(1)	(2)	(3)	(4)	(5)	(6)
$R\&D_{it}$	0.096***	0.059***	0.059***	0.065***	0.096***	0.458***
	(0.006)	(0.006)	(0.006)	(0.012)	(0.017)	(0.025)
$Coop_{it}$	35.394***	27.738***	28.194***	32.577***	61.218***	32.361***
	(3.083)	(2.816)	(2.873)	(4.408)	(3.448)	(2.714)
$Size_{it}$	0.194***	0.389***	0.389***	0.455***	0.737***	0.220***
	(0.013)	(0.014)	(0.014)	(0.022)	(0.052)	(0.014)
RDPersonRation	0.031***	0.022***	0.022***	0.028***	0.046***	-0.053***
	(0.002)	(0.002)	(0.002)	(0.004)	(0.006)	(0.006)
DRL_{it}	-0.592***	-0.790***	-0.783***	-1.056***	-1.985***	0.064
	(0.093)	(0.089)	(0.091)	(0.151)	(0.328)	(0.105)
$subsidy_{it}$	-0.011*	-0.009	-0.009	-0.005	0.001	0.008*
	(0.005)	(0.005)	(0.005)	(0.006)	(0.017)	(0.005)
-cons	0.814***	0.363***	0.359***	-0.267***	-4.650***	0.130*
	(0.058)	(0.059)	(0.059)	(0.115)	(0.825)	(0.059)
Observations	17742	17742	17726	6156	17742	17742
R^2	0.120	0.274	0.266	0.346		
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Enterprise Fixed Effects	No	Yes	Yes	Yes	Yes	Yes
Industry × Year Fixed Effects	No	No	Yes	No	No	No

4.3 Heterogeneity Tests

4.3.1 Heterogeneity Analysis of Enterprise Scale

To examine the possible moderating effect of enterprise scale, this paper divides the full sample into two groups: large-scale and small-scale enterprises according to the median of enterprise scale [22], and conducts regression estimation respectively. Columns (1) and (2) of Table 5 show the grouped regression results. It can be seen that both R&D investment and IUR cooperation density have positive effects on enterprise innovation output in both groups, but there are significant differences in the intensity of the effects.

Specifically, the promoting effect of R&D investment on innovation output of large-scale enterprises (column (1) of Table 5) is stronger than that of small-scale enterprises (column (2) of Table 5). This may be because large-scale enterprises usually have more complete R&D facilities and more abundant financial support, so they can more efficiently convert R&D resources into innovation achievements. In contrast, the improvement of IUR cooperation density on the innovation performance of large-scale enterprises is also significantly higher than that of small-scale enterprises. One possible explanation is that large-scale enterprises are often in a dominant position in cooperation and have stronger resource integration and technology digestion capabilities, thus being able to obtain more innovation benefits from IUR synergy.

The above results indicate that larger enterprises, by virtue of their stronger bargaining power, extensive social networks and higher technology absorption levels, have more advantages in integrating external knowledge and leading the cooperation process, thus obtaining higher innovation returns. Although small and medium-sized enterprises can also benefit from cooperation, their cooperation depth and breadth are relatively limited due to resource and capacity constraints

4.3.2 Heterogeneity Analysis of Enterprise Ownership

To examine the heterogeneity of the impact of R&D investment and IUR cooperation on enterprise innovation output under different ownership natures, this paper divides the full sample into state-owned enterprises and non-state-owned enterprises according to the ownership nature of enterprises, and conducts regression estimation respectively (Tang & Chen, 2025). Columns (3) and (4) of Table 5 present the grouped regression results.

The results show that both R&D investment and IUR cooperation have significant positive effects on enterprise innovation output in both state-owned and non-state-owned enterprises. However, there are differences in the degree of impact: specifically, the promoting effect of R&D investment on innovation output of state-owned enterprises is slightly higher than that of non-state-owned enterprises. This difference may stem from the fact that state-owned enterprises usually have more stable R&D funding support and longer-term innovation strategic planning, thus being able to more continuously convert R&D investment into innovation achievements.

Meanwhile, the study finds that IUR cooperation has a significantly stronger innovation-promoting effect on state-owned enterprises than on non-state-owned enterprises. This may be because state-owned enterprises have stronger capabilities in integrating resources from universities and research institutes, and their cooperative relationships with institutional scientific research subjects are often more stable and in-depth. The advantages of state-owned enterprises in the scale, resource guarantee and sustainability of cooperative projects enable them to obtain higher returns from cooperation.

The above results indicate that state-owned enterprises have institutional advantages in integrating external innovation resources, and the trust foundation and cooperation mechanism established between them and scientific research institutions are more mature, enabling them to more effectively absorb and transform knowledge spillovers generated by cooperation. In contrast, non-state-owned enterprises can also benefit from cooperation, but their marginal returns are relatively low due to limitations in resource acquisition channels and cooperation depth. In addition, the finding that the allocation efficiency of R&D personnel is higher in state-owned enterprises further confirms the comparative advantages of state-owned enterprises in the cultivation and performance of innovative talents.

4.3.3 Heterogeneity Analysis of Enterprise Technology Intensity

According to the definition of industry technology intensity by the U.S. Department of Commerce, an industry is considered a high-tech industry if its R&D expenditure accounts for 5% or more of enterprise sales. This paper divides the sample into two groups: high-tech industries (*high_tech*=1) and traditional industries (*high_tech*=0) according to enterprise technology intensity, and conducts regression estimation respectively.

The results in columns (5) and (6) of Table 4 show that in the traditional industry group, R&D investment shows a significant and large promoting effect on enterprise innovation output; while in the high-tech industry group (column (5)), this effect is relatively weak, and the impact of R&D investment is positive but not significant. This may be because the R&D activities of high-tech enterprises often involve more basic research and cutting-edge technology exploration, which have the characteristics of long cycles, high risks and great uncertainty, leading to diminishing marginal returns of R&D investment. In contrast, the R&D activities of low-tech enterprises (column (6) of Table 5) are mostly application-oriented and improvement-oriented, which can be more quickly converted into market-oriented innovation outputs.

However, IUR cooperation density shows a significant positive effect in both high-tech and traditional industry groups, but with different degrees of impact. This indicates that external knowledge acquisition is of important value to enterprises at different technological levels, and the marginal effect is greater for low-tech enterprises.

Table 5. Heterogeneity Test Results

Explained Variable： IO_{it}	（1）	（2）	（3）	（4）	(5)	(6)
$R\&D_{it}$	0.066^{***}	0.051^{***}	0.065^{***}	0.059^{***}	0.006	0.303^{***}
	(0.010)	(0.007)	(0.012)	(0.007)	(0.008)	(0.019)
$Coop_{it}$	31.180^{***}	21.32^{***}	32.580^{***}	24.350^{***}	15.820^{***}	32.330^{***}
	(4.044)	(3.857)	(4.408)	(3.618)	(5.226)	(3.222)
$Size_{it}$	0.420^{***}	0.476^{***}	0.455^{***}	0.380^{***}	0.488^{***}	0.293^{***}
	(0.027)	(0.029)	(0.022)	(0.018)	(0.034)	(0.014)
RDPersonRation	0.020^{***}	0.022^{***}	0.028^{***}	0.019^{***}	0.006^{**}	0.019^{***}
	(0.003)	(0.002)	(0.004)	(0.002)	(0.003)	(0.003)

DRL_{it}	-0.780***	-0.685***	-1.056***	-0.624***	-0.843***	-0.518***
	(0.153)	(0.108)	(0.151)	(0.114)	(0.195)	(0.096)
$subsidy_{it}$	-0.008	-0.012	-0.005	-0.0152*	0.069*	-0.002
	(0.007)	（0.006)	(0.006)	(0.008)	(0.037)	(0.005)
-cons	-0.027	0.346***	-0.267***	0.571***	1.423***	0.030
	(0.143)	(0.088)	(0.115)	(0.072)	(0.149)	(0.062)
R^2	0.300	0.264	0.346	0.239	0.138	0.277
Observations	8866	8872	6156	11585	5618	12121
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Enterprise Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

5. Research Conclusions and Policy Implications

The empirical study based on the data of listed companies from 2015 to 2020 shows that enterprises' internal R&D investment and industry-university-research cooperation are key driving forces to improve enterprise innovation performance. The main research conclusions are as follows.

(1) Enterprise internal R&D investment and external IUR cooperation, as the dual driving forces of innovation, have a significant improvement effect on enterprise innovation output. Moreover, this conclusion still holds after robustness tests and endogeneity treatment, confirming that enterprise innovation activities require both internal knowledge accumulation and external knowledge acquisition.

(2) Through multi-dimensional heterogeneity analysis, it is found that enterprise scale is an important regulating factor. Large-scale enterprises, with their abundant resource endowments and strong absorption capacity, can obtain far more innovation returns from IUR cooperation than small and medium-sized enterprises. At the same time, the nature of enterprise ownership also shows differences in collaboration efficiency. State-owned enterprises show obvious institutional advantages in IUR collaboration due to their close ties with institutional universities and research institutions. In addition, the study also finds that industrial technical attributes have an impact on enterprise innovation paths. Different from traditional cognition, in traditional industries with relatively weak technical foundation, the improvement effect of IUR cooperation on innovation output is more significant.

(3) It should be pointed out that the overall density of IUR cooperation at the level of Chinese listed companies is currently low, reflecting that the interaction between enterprises and universities, research institutions is still at a relatively shallow level. How to break through the limitations of current low-level cooperation and promote cooperation from formalization to substantiation is an urgent task to improve the national innovation system.

Based on the above conclusions, this paper puts forward the following practical implications.

(1) Government level: Implement classified policy measures. For large state-owned enterprises and

industry leaders, the policy orientation should shift from universal subsidies to strategic incentives, guiding them to establish innovation alliances aimed at technological breakthroughs. Core indicators such as the transformation efficiency of IUR achievements and the cross-industry chain technology radiation effect should be included in the evaluation system to strengthen the leading responsibility of enterprises as leading enterprises in the industrial chain and the function of ecosystem construction. For small and medium-sized enterprises, focus on promoting policy tools such as innovation vouchers and post-subsidies for R&D expenses, establish a regional IUR interconnection digital platform, and systematically overcome collaboration bottlenecks such as information asymmetry and lack of trust mechanism. For different industrial types, set up special guidance funds for the digital transformation of traditional manufacturing industries to promote IUR collaboration to empower industrial upgrading. Establish long-term cutting-edge technology exploration funds for high-tech industries to support in-depth IUR cooperation in the fields of basic research and original innovation.

(2) Enterprise level: Consolidate the R&D foundation and establish a sustainable R&D investment mechanism. Leading enterprises should actively build innovation networks, establish professional collaborative management institutions, scan external technical opportunities, accurately match academic and research resources according to needs, promote the transformation from project cooperation to in-depth collaboration models such as co-constructed laboratories, and embed external knowledge flow into the entire innovation chain.

This study has certain limitations. First, the sample is limited to listed companies, and failed to deeply study unlisted small and medium-sized innovative enterprises. Second, the study mainly focuses on the quantity of enterprise innovation output. Future research can further explore the impact of collaboration "quality" and "mode". Finally, the innovation process is dynamic and cumulative. Future research can adopt methods such as dynamic panel models to more deeply investigate the lag effect and long-term law of the impact of R&D and cooperation.

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