1 The Path of Profit Model Transformation Driven by R&D Investment

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Abstract

The heterogeneous conclusions on the impact of R&D investment on performance are direct evidence of the black box of R&D investment output. Continuing to study the direct impact of R&D investment on performance makes it difficult to break this black box. According to the logic that the output of R&D investment first results in patents and only through patent operation can generate revenue, it is necessary to examine the impact of patent operation levels on performance, indirectly reflecting the impact of dormant patents and proprietary technology on performance. Second, to reduce the failure rate of R&D, it is crucial to emphasize the role of high total factor productivity in the efficiency of R&D resource allocation rather than solely focusing on how R&D investment promotes total factor productivity, especially when high R&D failure rates cannot improve the future level of total factor productivity in firms. The role of total factor productivity, represented by the level of R&D human capital and R&D equipment, in promoting R&D success becomes prominent. Based on this, this study takes industrial firms in 18 cities in Henan Province from 2012 to 2019 as the research sample, with patent operation as the mediating variable and total factor productivity as the moderating variable, to construct a moderated mediation model to test the impact of R&D investment on profit model transformation. The study found: (1) The level of patent operation played a partial mediating role, with the direct effect of R&D investment accounting for a larger proportion. This is due to the high number of dormant patents or firms operating with proprietary technology; thus, emphasizing the role of proprietary technology and high-quality patent operation provides evidence for breaking the black box of R&D investment output. (2) Total factor productivity did not play a moderating role in the first half of the path, indicating that R&D is not just a matter of hard investment; other factors such as institutional, cultural, enthusiasm, and loyalty of R&D personnel, and other soft strengths are

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more important. Total factor productivity cannot hedge against the high uncertainty from R&D investment to patent output. This conclusion provides a reference for deepening the research on the black box of R&D investment output. (3) Total factor productivity played a moderating role in the latter half of the path, indicating that the uncertainty between high-quality operation and the level of intellectual property income, represented by new product sales revenue and technical service income, is reduced. Under the role of higher total factor productivity, this uncertainty is further reduced. This conclusion provides evidence for breaking the black box of R&D investment output. Therefore, only a virtuous cycle between higher total factor productivity and R&D investment can significantly promote the transformation of profit models. However, it is essential to emphasize high-quality patent cultivation projects and the role of proprietary technology. The results have reference value for the transformation and upgrading of firms and the adjustment of China's intellectual property strategy.

Keywords: R&D; black box; patent operation; total factor productivity; intellectual property income; profit model transformation

JEL Classification: D80, O34, C12

1. Introduction

The shift from the notion of "no R&D means certain death, R&D means possible death" to the philosophy of "mass innovation, mass entrepreneurship" indicates that innovation is now the cornerstone of firm survival and development. However, unraveling the black box of R&D output remains a challenging task. Heterogeneous research conclusions on the impact of R&D investment on performance have provided evidence: linear relationships show a positive correlation (Huang et al., 2018), a negative correlation (Lin et al., 2006), and no correlation (Silva et al., 2015); nonlinear relationships present inverted U-shaped (Booltink and Saka-Helmhout, 2018), inverted N-shaped (Dong and Han, 2016), and horizontal S-shaped conclusions (Lee, 2009). Furthermore, numerous studies have explored various perspectives, such as the professional background of entrepreneurs, management teams, regional institutional differences, corporate governance, internal controls, government subsidies, market structures, corporate heterogeneity, intellectual capital, cash holdings, capital structures, CEO compensation, market-oriented reforms, political connections, competitive strategies or diversification strategies, social capital, venture capital, advertising expenditures, technological capabilities, technology spillovers, modes of technology acquisition, nature of ownership, and heterogeneous shareholders. These studies have enriched the literature on the impact of R&D investment on performance, yet heterogeneous research conclusions such as positive, negative, and no correlations persist, making the black box of R&D output difficult to break.

The output of R&D investment initially manifests as patents, which subsequently generate revenue through patent operations. In its early stages, the concept of patent operation was confined to general business management, focusing on how firms could leverage patents to develop technologies and product markets. With the deepening of open innovation principles, patent operations have extended beyond internal corporate activities to external transactions, such as selling patent rights to other entities, transferring or licensing patent usage rights for revenue, or utilizing patent property rights for financing in capital markets. Additionally, studies (e.g., Cui and Liu, 2017) have recognized patent protection (litigation) as an indirect means of enhancing the value of patents, thus becoming a focal point of related research. There has emerged a trend of entities that do not engage in product manufacturing or R&D but instead purchase patents to pursue litigation for damages or to coerce manufacturers into accepting patent licensing agreements for profit, known as non-practicing entities (NPEs) (Duffy, 2010).

Given the evolving nature of patent operations, which continuously enriches its connotations and expands its scope, the intrinsic value of patents as intangible assets remains consistent in their potential for value appreciation through movement. This study posits that patent operation encompasses the strategies and methods employed by firms to realize the value of patent assets, including the creation and acquisition of patents, patent standardization, productization, commercialization, capitalization, and protection.

From a practical standpoint, a linear relationship between R&D investment and profit is apparent only when the success rate of R&D is relatively high. Otherwise, the profits following R&D investment typically exhibit irregular fluctuations. In line with the principle of matching revenue with expenses, the alignment between R&D investment and intellectual property (IP) revenue is more pronounced than that between R&D investment and profit. IP revenue comprises new product sales income, patent licensing, transfer income, and returns from IP investments. Zhou (2014) asserted that the crux of transformation and upgrading lies in the innovation of profit models; without innovative profit models, discussions of strategy, branding, technology, and even business models cannot sustain competitive advantage. Xiao et al. (2019), through questionnaire data, found varying impacts of patent creation, application, and protection capabilities on corporate performance. It can be inferred that without increasing IP revenue, transforming the profit model is unfeasible. Thus, selecting the proportion of IP revenue post-R&D investment as an indicator of profit model transformation and studying it along the “R&D - Patent Operation - Profit Model Transformation” chain is feasible. The conclusions provide a significant reference value for unraveling the black box of corporate R&D output.

This study posits a proposition: the path and structure of China’s economic growth post the 18th National Congress will undergo profound changes, marking a new inflection point for the national profit model. The realization of this new inflection point in the national profit model is contingent upon the transformation of industrial profit models, which in turn relies on the transformation of profit models in high-tech firms. The shift in high-tech firms’ profit models from traditional product-based to intellectual property-based is essential, and this transition cannot be achieved without increased R&D investment. However, existing research has not successfully addressed the black box of R&D investment output. Therefore, selecting the proportion of intellectual property revenue post-R&D investment to represent profit model transformation, incorporating the mediating variable of patent operation levels and the moderating variable of total factor productivity, strengthens the study of the mechanism by which R&D investment affects performance. This aims to provide evidence for unveiling the black box of corporate R&D output.

Compared to existing literature, the contributions of this study are as follows. First, it breaks the conventional mismatch between R&D investment and corporate performance. Since corporate performance reflects the net result of all revenues minus all expenses, the intellectual property (IP) revenue generated from R&D investment constitutes only a portion of the firm’s profit. Enhancing the proportion of IP revenue in high-tech firms is crucial for promoting sustainable development, thus aligning R&D investment with IP revenue.

Second, it reveals the impact of patent operation levels on the transformation of profit models. China has ranked first in the world for nine consecutive years in terms of the number of invention patent applications, yet it remains distant from being an innovation powerhouse. This discrepancy highlights underlying issues with patent quality and sustained innovation quality. To unravel the black box of R&D investment output, attention must be paid to the level of patent operations. If the direct mediating effect of patent operations is modest, it underscores the contribution of proprietary technology to profit models, an area previously underexplored.

Third, since the total factor productivity (TFP) of firms comprehensively reflects their current resource allocation efficiency, an improvement in the allocation efficiency of production factors enhances patent operation levels and facilitates profit model transformation. Therefore, it is insufficient to study how R&D investment promotes TFP merely. Particularly when a high R&D failure rate does not improve the future TFP level of firms, the current TFP, represented by the level of R&D human capital and R&D equipment, plays a crucial role in promoting R&D success.

Hence, this study emphasizes the interactive effects of TFP with R&D and patent operations on the transformation of profit models.

The implications of this study are as follows. First, to unlock the black box from R&D investment to corporate performance, it is essential to use intellectual property revenue as a metric for R&D output, with a focus on the mediating effect of patent implementation rates. This approach will facilitate China's transition from a major patent producer to a patent powerhouse while also acknowledging the significance of proprietary technology. Second, the total factor productivity, established on the comprehensive levels of human capital and R&D equipment, significantly promotes patent operation levels and the transformation of profit models in high-tech firms. This, in turn, reduces inefficient R&D investments.

2. Research Design

2.1. Theoretical Analysis and Research Hypotheses

Although conclusions about the impact of R&D investment on corporate performance are inconsistent, R&D is the source of innovative outputs. The hypothesis that R&D investment positively influences corporate performance is valid. The heterogeneous conclusions arise because there are numerous uncertain or unknown factors - termed the black box - between the starting point of R&D investment and the endpoint of corporate performance. These uncertainties are embedded within the chain of R&D investment, formation of intellectual property, IP operations, IP revenue, and the transformation of corporate profit models. This chain can be broadly divided into two stages: the first stage is the formation of intellectual property capital, and the second stage involves the economic consequences of IP capital operations.

In the first stage, whether R&D investment leads to an improvement in patent technology levels is an uncertain factor. Cai and Yu (2017) contend that firms can only achieve favorable innovation outcomes by simultaneously focusing on both the quality and quantity of innovation. Despite China leading the world in the number of invention patent applications for nine consecutive years, it has yet to become an innovation powerhouse, underscoring the urgency for Chinese firms to pursue patent quality. The essence of patent quality lies in its technological foundation; without solid technology and innovation, even if a patent is granted, it remains a dormant patent. High-quality patents are the cornerstone of value-added patent operations. If R&D investment results in numerous dormant patents, these typically become liabilities for the firm.

However, if a firm invests heavily to establish intellectual property barriers, this does not necessarily constitute a liability. Nevertheless, overall, patent technology monopolies hinder societal technological advancement. Therefore, China's Patent Law explicitly provides for compulsory licensing of patents. Moreover, with the rapid pace of technological updates, the patent risks for firms increase, particularly when firms face financial difficulties. In such scenarios, intellectual property barriers are not the optimal strategy.

Only through patent operations can performance be generated. Feng (2014) asserts that patent operations represent the process by which firms utilize intellectual property to create value and preserve or enhance the value of intellectual property. The positive impact of patent commercialization on technological innovation performance is particularly significant (Cao et al., 2012). Mauck and Pruitt (2015) argue that the "OT300 Patent Index," jointly released by OceanTomo and the American Stock Exchange, plays a practical role in scientifically evaluating the performance of corporate patent operations and predicting the value of corporate innovation.

The commercialization of research outcomes exemplifies the profit model of intellectual property as marketable products (Gianluca et al., 2021). Knowledge-based small firms leverage intellectual property strategies to secure funding, enhance their scientific reputation, attract new technologies, and facilitate development (Christopher et al.,2021). Innovative firms that profit from intellectual property exhibit higher profitability, with their innovative capacity being positively correlated with sustainable profitability and higher future stock returns (Bedford et al., 2021).

Drawing on existing research, the fundamental forms of patent operations include standardization, productization, commercialization, and capitalization (Torrisi et al., 2016; Yang and Jiang, 2017). These operations even encompass aspects such as patent application, transformation, trade, litigation, maintenance, and talent cultivation (Zhou and Zuo, 2019), constituting a broad definition of patent operations.

Given that R&D investment results in patents and patent operations drive profit model transformation, the following hypothesis is proposed:

Hypothesis 1: *Patent operation levels mediate the relationship between R&D investment and profit model transformation.*

The efficiency of innovation investment is the result of the rational and effective allocation of fundamental resources such as human labor, capital, and materials in technological innovation activities (Fan and Du, 2018). The transformation of complex patent technologies necessitates greater investment in human and financial resources, along with comprehensive supporting resources (Li and Wei, 2016). Corporate patent operation performance measures and provides feedback on the extent to which a firm utilizes its controlled patent production factors to achieve its technological and commercial objectives (Zhou and Zuo, 2019).

Dang et al. (2015) used the relative gap between China's total factor productivity (TFP) and that of the United States as a proxy for the technology gap, empirically demonstrating that the technology gap significantly impacts the technological innovation performance of China's high-tech industries. Qin (2018) identified internal management factors and external environmental factors affecting efficiency, finding that poor internal management is the primary reason for the backwardness of China's western regions compared to other areas. Patent operations effectively convert technology into actual productive capacity (Wang and Li, 2011).

These studies indicate that a firm's total factor productivity comprehensively reflects its current technological level and resource allocation efficiency. Only R&D investment based on high total factor productivity can overcome dependence on low human capital and technical equipment, thereby enhancing corporate patent operations. The following hypothesis is proposed:

Hypothesis 2*: The interaction between total factor productivity and R&D investment promotes patent operation levels.*

The productization of patents generates new product sales revenue for firms, while the commercialization of patents directly contributes to corporate income. Patent securitization enables market financing, enhancing the capability of patent productization, and patent standardization ultimately reflects in the revenue from new products. Therefore, the level of patent operations is a critical factor in increasing new product sales revenue, patent licensing income, technical service income, and other intellectual property revenues.

Patent technology has an unequivocally positive effect on enhancing innovation performance (Chang et al., 2012), and patent licensing significantly promotes corporate innovation output (Liu et al., 2015). In a dynamic, highly competitive, high-tech environment, a high-quality patent portfolio can yield returns through commercialization, with patent commercialization having a particularly significant positive impact on technological innovation performance (Cao et al., 2012).

As the total factor productivity (TFP) of firms comprehensively reflects their current resource allocation efficiency, patent operations built on high TFP can better facilitate the transformation of profit models. Thus, there is an inherent connection between TFP and patent operations in advancing corporate profit model transformation. The following hypothesis is proposed:

Hypothesis 3: *The interaction between total factor productivity and patent operation levels promotes the transformation of profit models.*

2.2 Variable Selection

Dependent Variable (NP): Profit Model Transformation. Given the availability of data, the proxy variable for the profit model transformation is represented by the ratio of the sum of new product sales revenue and patent licensing and transfer income to the main business income.

Moderating Variable (TFP): Total Factor Productivity. This study follows the methodology of Yuan and Li (2018), utilizing the SE-DEA model for calculation. The output variables reference Qu's (2016) approach, using 2012 as the base year and deflating GDP with the industrial producer price index. The perpetual inventory method is employed to calculate the physical capital stock using the formula:

$$K_t = K_{t-1}(1-\delta) + I_t ,$$

where K_t represents the capital stock in year t, K_{t-1} represents the capital stock in year t-1, I_t represents the fixed asset investment in year t, and δ denotes the depreciation rate, set at 9.16% (Zhang et al., 2004). The base period capital stock is calculated following the method of Cheng and Lu (2014). Labor input is represented by the average number of employees in industrial firms above a designated size in each city.

Mediating Variable (PI): Patent Operation Level. The basic criteria for determining patent quality include whether the patents designed by the inventors meet essential factors such as high innovation level, stable market share, and stable legal status. High-quality patents are characterized by conformity to design standards, high dependence on industrial development, and significant overall industrial scale. Compared to indicators such as the number of patent citations, citation frequency, patent applications, and patent grants, the patent implementation rate better represents the operational level of intellectual property capital and its role in transforming profit models. Patent implementation is inseparable from patent protection. Following Hu et al. (2012) approach, the ratio of regional technology market transaction turnover to GDP is used to represent patent protection strength. The higher this ratio, the greater the patent value per unit of GDP, indicating more effective regional patent protection and more active technology market transactions. This study measures the patent operation level using both the invention patent implementation rate and the patent protection strength indicator, employing the entropy weight method to derive a comprehensive index of the patent operation level.

Independent Variable (RD): R&D Investment. The ratio of the sum of internal and external R&D expenditure to main business income represents this.

Control Variables: These include the asset-liability ratio of industrial firms in each region (LEV), as well as regional (Area) and annual (Year) dummy variables.

The definitions of the variables are shown in Table 1.

Table 1: Variable Definitions

Type	Name	Symbol	Definition
Dependent Variable	Profit Model Transformation	NP	Proportion of intellectual property revenue to main business income
Moderating Variable	Total Factor Productivity	TFP	Calculated using the SE-DEA model
Mediating Variable	Patent Operation Level	PI	Invention Patent Implementation Rate = Number of Implemented Invention Patents in the Current Year / Number of Effective Invention Patents at Year-End Patent Protection Intensity = Technology Contract Turnover in the Current Year / Gross

Type	Name	Symbol	Definition
			Domestic Product in the Current Year (Composite index of patent operation level calculated using the entropy weight method)
Independent Variable	R&D Investment	RD	The ratio of the sum of internal and external R&D expenditure to main business income
Control Variables	Financial Leverage Region Year	LEV Area Year	Total Liabilities / Total Assets. Assigned a value of 1 if within the region, otherwise 0 Assigned a value of 1 for the current year, otherwise 0

2.3 Data Sources and Model Construction

2.3.1 Data Sources

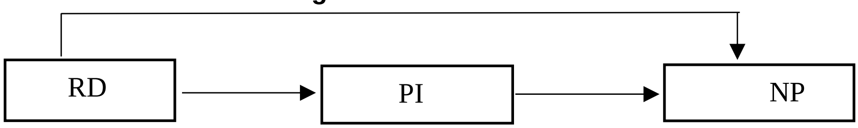
Given that some annual figures on the implementation of invention patents have been disclosed for various regions in Henan Province. At the same time, other provinces in mainland China have not provided such data. This study uses industrial firms from 18 cities in Henan Province from 2012 to 2019 as the research sample. The data is sourced from the "Henan Statistical Yearbook" and "Henan Science and Technology Statistical Yearbook" for the years 2013 to 2020. Due to the lack of data on the implementation of invention patents prior to 2014, the annual average growth rate of the number of implemented invention patents from 2014 to 2016 in each region is used to estimate the data for 2012 and 2013, thus compensating for the insufficiency of the sample size.

2.3.2 Model Construction

Since it typically takes two years or more from the application to the authorization of an invention patent, this study employs a two-year lag for R&D investment.

The mediation model is illustrated in Figure 1.

Figure 1: Research Model



Based on Figure 1, the following sequential equations (1), (2), (3), and (4) are established for testing.

$$NP_{i,t} = \alpha_0 + \alpha_1 RD_{i,t-2} + LEV_{i,t} + \varepsilon_{\mathrm{i,t}} \quad (1)$$

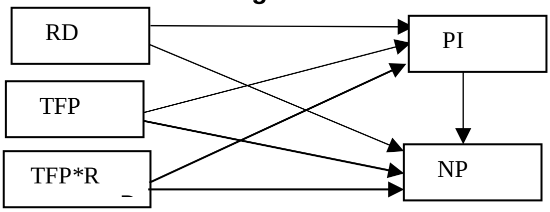
$$PI_{i,t} = \beta_0 + \beta_1 RD_{i,t-2} + LEV_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$NP_{i,t} = \rho_0 + \rho_1 PI_{i,t} + LEV_{i,t} + \varepsilon_{\mathrm{i,t}} \quad (3)$$

$$NP_{i,t} = \gamma_{0+}\gamma_1 RD_{i,t-2} + \gamma_2 PI_{i,t} + LEV_{i,t} + \varepsilon_{\mathrm{i,t}} \quad (4)$$

The moderated mediation model is illustrated in Figure 2.

Figure 2: Moderated Mediation Model



Based on Figure 2, TFP*RD represents the moderating effect term. If it influences PI, and PI subsequently influences NP, this indicates that the moderating effect (at least partially) operates through the mediating variable PI. Sequential equations (5), (6), and (7) are established for testing. If coefficients μ_3, θ_3 and τ_3 are all significant, and the significance of τ_3 decreases compared to μ_3, it implies that PI mediates the relationship between TFP*RD and NP. If the sequential tests do not pass, further validation will be conducted using the bias-corrected percentile Bootstrap interval method.

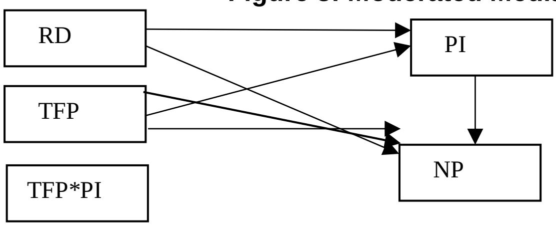
$$NP_{i,t} = \mu_0 + \mu_1 RD_{i,t-2} + \mu_2 TFP_{i,t} + \mu_3 TFP_{i,t} \times RD_{i,t-2} + LEV_{i,t} + \varepsilon_{i,t} \tag{5}$$

$$I_{i,t} = \theta_0 + \theta_1 RD_{i,t-2} + \theta_2 TFP_{i,t} + \theta_3 TFP_{i,t} \times RD_{i,t-2} + LEV_{i,t} + \varepsilon_{i,t} \tag{6}$$

$$NP_{i,t} = \tau_0 + \tau_1 RD_{i,t-2} + \tau_2 TFP_{i,t} + \tau_3 TFP_{i,t} \times RD_{i,t-2} + \tau_4 PI_{i,t} + LEV_{i,t} + \varepsilon_{i,t} \tag{7}$$

The moderated mediation model is illustrated in Figure 3.

Figure 3: Moderated Mediation Model



According to Figure 3, TFP does not moderate the relationship between RD and NP but rather moderates the relationship between PI and NP. This implies that the mediating effect of PI is influenced by the moderating variable TFP, making PI a moderated mediator. Sequential equations (8), (9), (10), and (11) are established for testing. If the RD coefficient δ_1 in the model (8) is significant, proceed to test the RD coefficient π_1 in the model (9); if significant, continue to test the PI coefficient φ_3 in model (10). If significant, it indicates that the mediating effect of PI is significant. Then, test the significance of the moderating effect coefficient ϑ_4 for $TFP_{i,t} \times PI_{i,t}$. If the sequential tests do not pass, further validation will be conducted using the bias-corrected percentile Bootstrap interval method.

$$NP_{i,t} = \delta_0 + \delta_1 RD_{i,t-2} + \delta_2 TFP_{i,t} + LEV_{i,t} + \varepsilon_{i,t} \tag{8}$$

$$PI_{i,t} = \pi_0 + \pi_1 RD_{i,t-2} + \pi_2 TFP_{i,t} + LEV_{i,t} + \varepsilon_{i,t} \tag{9}$$

$$NP_{i,t} = \varphi_0 + \varphi_1 RD_{i,t-2} + \varphi_2 TFP_{i,t} + \varphi_3 PI_{i,t} + LEV_{i,t} + \varepsilon_{i,t} \tag{10}$$

$$NP_{i,t} = \vartheta_0 + \vartheta_1 RD_{i,t-2} + \vartheta_2 TFP_{i,t} + \vartheta_3 PI_{i,t} + \vartheta_4 TFP_{i,t} \times PI_{i,t} + LEV_{i,t} + \varepsilon_{i,t} \tag{11}$$

3. Empirical Results and Analysis

3.1. Descriptive Statistics

The descriptive statistics of the main variables are presented in Table 2.

Table 2: Descriptive Statistics of Main Variables

Variable	Sample Size	Minimum	Maximum	Mean	Standard Deviation
RD	114	0.001	0.019	0.055	0.033
PI	144	0.009	0.401	0.128	0.061
TFP	144	0.223	1.000	0.576	0.179
LEV	144	0.251	0.669	0.454	0.105
NP	144	0.039	0.271	0.063	0.052

Source: Author's Construction

Table 2 shows that the mean values of R&D (RD), patent operation level (PI), and intellectual property revenue level (NP) are relatively low. These represent the initial input, intermediate output, and final output levels of the profit model transformation chain, indicating that the sample industrial firms face significant pressures in their transformation and upgrading processes. The mean value of total factor productivity (TFP) is moderate, providing a solid foundation for the moderating role of R&D investment to output. The mean value of financial leverage (LEV) is also moderate, indicating that the financial risk pressure is not substantial.

3.2 Correlation Analysis

Pearson correlation coefficients were calculated for the variables, with the results presented in Table 3.

Table 3: Pearson Correlation Coefficients of Variables

	NP	RD	TFP	PI
NP	1			
RD	0.412***	1		
TFP	0.303***	-0.237*	1	
PI	0.226**	0.477***	0.039	1

Table 3 indicates that, after controlling for the asset-liability ratio, R&D investment, total factor productivity, and patent operation levels are positively correlated with profit model transformation. The magnitude of the correlation coefficients provides a preliminary indication of the impact of each variable on the dependent variable. Most of the absolute values of the correlation coefficients are below 0.5, suggesting that there is no serious multicollinearity among the variables, thus allowing for regression analysis based on the established model.

3.3 Regression Results Analysis

Table 4 presents the regression results of the mediation effects.

Table 4: Regression Results of Models 1-4

Variable	Model 1	Model 2	Model 3	Model 4
RD	10.102*** (3.294)	10.239** (2.526)		7.327** (2.665)
PI			0.289* (1.892)	0.271**(2.482)
LEV	0.129*** (3.002)	0.135** (2.563)	0.161*** (3.115)	0.147*** (3.011)
Region Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Constant	0.001 (0.243)	0.036*** (4.047)	0.025 (0.677)	-0.001 (-0.022)
Adj.R^2	0.214	0.203	0.187	0.272
N	108	108	108	108

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

Table 4 shows that the coefficient of R&D investment in Model 1 is significantly positive at the 1% level, indicating that R&D investment has a significant positive impact on profit model transformation. In Model 2, the coefficient of R&D investment is significantly positive at the 5% level, suggesting that R&D investment significantly impacts patent operation. The coefficient of patent operation in Model 3 is significantly positive at the 10% level, indicating that patent operation significantly influences profit model transformation. In Model 4, the coefficient of patent operation is significantly positive at the 5% level, and the coefficient of R&D investment also passes the significance test. This indicates that patent operation plays a partial mediating role in the relationship between R&D investment and profit model transformation, with the mediating effect accounting for 27.47% of the total effect and the ratio of the mediating effect to the direct effect being 37.87%. Thus, Hypothesis 1 is validated.

The direct effect of R&D investment is relatively large, which may be due to the presence of numerous dormant patents or the extensive use of proprietary technology in operations.

Table 5 shows that in Model 5, the interaction term between total factor productivity and R&D investment is significantly positively correlated with profit model transformation. However, in Model 6, the interaction term does not significantly affect patent operation levels, failing the sequential test method. Further validation using the bias-corrected percentile Bootstrap interval method, $\theta_3\tau_4$ within the 95% confidence interval [LLCI=-0.238, ULCI=3.6801], indicates that patent operation levels do not mediate the relationship between the interaction term of R&D investment and total factor productivity and profit model transformation. Thus, Hypothesis 2 is not validated.

One of the primary aims of Hypothesis 2 was to ascertain whether current levels of total factor productivity enhance the positive impact of R&D investment on patent operation levels, but this was not supported. This result is attributed to the complex influencing factors of R&D investment. R&D is not merely a matter of tangible investment; the influence of intangible factors such as institutional frameworks, culture, and the enthusiasm and loyalty of R&D personnel is more significant. Total factor productivity cannot mitigate the high uncertainty from R&D investment to patent output.

In Models 8 and 9, the coefficients for R&D investment are significant at the 1% level, and the coefficient for patent operation levels in Model 10 is significant at the 5% level, indicating a significant mediating effect of patent operation levels. In Model 11, the coefficient for the interaction term between total factor productivity and patent operation levels is significantly positive at the 1% level, indicating that total factor productivity moderates the latter half of the pathway. Thus, Hypothesis 3 is validated.

Table 5: Regression Results of Models 5-11

Variable	Model 5	Model 6	Model 8	Model 9	Model 10	Model 11
RD	-3.776 (-0.781)	3.753 (0.606)	11.425*** (7.862)	10.932*** (5.343)	10.014*** (5.301)	10.012*** (6.343)
PI					0.159** (2.252)	-0.764*** (-3.166)
TFP	-0.028 (-1.311)	-0.047 (-0.503)	0.167*** (7.132)	0.031 (1.044)	0.126*** (6.411)	-0.037 (-0.841)
TFP*RD	27.712*** (3.387)	13.336 (1.026)				
TFP*PI						1.521*** (4.021)
LEV	0.284 (0.812)	0.053 (0.177)	0.117** (2.24)	0.133* (1.648)	0.113*** (3.21)	0.112 (1.241)
Region Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.0096 (0.035)	0.081 (1.576)	-0.089*** (-5.648)	0.026 (1.407)	-0.068*** (-5.112)	0.014 (0.452)
Adj R^2.	0.526	0.311	0.512	0.232	0.534	0.589
N	108	108	108	108	108	108

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

3.4 Robustness Test

Green innovation extends the traditional concept of innovation, emphasizing innovation output that reduces environmental pollution, raw materials, natural resources, and energy usage. Enhancing innovation performance and green innovation performance are crucial indicators of profit model transformation. Green innovation output can serve as a proxy variable for the profit model transformation, as per Liu et al. (2019), using the ratio of new product sales revenue to total energy consumption to represent green innovation performance.

Repeating the aforementioned regression steps, the results are shown in Tables 6 and 7.

Table 6: Robustness Test Results for Models 1-4

Variable	Model 1	Model 2	Model 3	Model 4
RD	4.216** (2.213)	7.314*** (3.582)		3.177* (1.663)
PI			0.106** (2.317)	0.142** (2.424)
LEV	0.102** (2.101)	0.103*** (2.773)	0.147*** (3.137)	0.118** (2.227)
Region Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Constant	0.012 (1.431)	0.047*** (4.201)	0.011 (1.522)	0.005 (0.613)
Adj.R^2	0.215	0.223	0.274	0.299
N	108	108	108	108

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

As shown in Table 6, the regression results did not undergo substantial changes. The mediating effect of patent operation level in the relationship between R&D investment and profit model transformation slightly decreased. The proportion of the mediating effect relative to the total effect decreased from the original 27.47% to 24.63%, and the ratio of the mediating effect to the direct effect decreased from 37.87% to 32.69%.

Table 7: Robustness Test Results for Models 5-11

Variable	Model 5	Model 6	Model 8	Model 9	Model 10	Model 11
RD	-8.712** (-2.103)	3.531 (0.465)	4.512*** (3.567)	10.713***（5.015）	3.856***（2.532）	3.718*** (2.728)
PI					0.081* (1.692)	-0.528*** (-3.105)
FP	-0.044 (-0.957)	-0.023 (-0.416)	0.107*** (5.513)	0.021 (1.039)	0.191*** (5.574）	-0.055 (-1.181)
TFP*RD	24.446*** (3.317)	13.778 (1.057)				
TFP*PI						1.202*** (3.733)

Variable	Model 5	Model 6	Model 8	Model 9	Model 10	Model 11
LEV	0.043* (1.482)	0.068 (0.178)	0.107* (1.648)	0.147* (1.704)	0.111*** (3.25)	0.115 (1.13)
Region Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.041 (0.83)	0.073 (1.451)	-0.043*** (-3.648)	0.019 (1.216)	-0.021*** (-3.811)	0.0236 (0.586)
Adj R^2.	0.327	0.231	0.257	0.213	0.279	0.376
N	108	108	108	108	108	108

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

Table 7 shows that in Model 5, the interaction term between total factor productivity and R&D investment is significantly positively correlated with profit model transformation. The dependent variable in Model 6 did not change, which is consistent with the original conclusion, indicating that total factor productivity does not moderate the first half of the pathway, and Hypothesis 2 is not validated. The coefficients for R&D investment in Models 8 and 9 are significant at the 1% level, the coefficient for patent operation level in Model 10 is significant at the 10% level, and the interaction term between total factor productivity and patent operation level in Model 11 is significantly positive at the 1% level. This indicates that total factor productivity moderates the latter half of the pathway.

The combined regression results in Tables 6 and 7 demonstrate that the conclusions of this study are robust.

3.5 Endogeneity Test

The transformation of profit models requires firms to possess intellectual property and enhance their ability to create high-end value, necessitating increased R&D investment in high-tech technologies. Therefore, there may be a reverse causality issue leading to endogeneity between R&D investment and profit model transformation. To mitigate endogeneity, this study employs the natural logarithm of the number of regional R&D institutions and the scale of regional industrial firms as instrumental variables.

Table 8 reports the results of the endogeneity test. First, the Hausman test (X^2=22.74, P=0.0000) indicates the necessity of selecting instrumental variables, as the null hypothesis of no endogenous explanatory variables cannot be rejected. Second, the F-value of the first-stage regression is 17.14, greater than the empirical value of 10, suggesting no weak instrumental variables. Finally, the KP-LM statistic is 24.514, significantly rejecting the null hypothesis of under-identification of instrumental variables at the 1% level. The Hansen J statistic's P-value is 0.1239, indicating no significant statistical evidence to reject the null hypothesis that all instrumental variables are exogenous, confirming the validity of the selected instrumental variables.

From column (2) of the second-stage regression, the RD coefficient is 10.0513, remaining significantly positive at the 1% level, thus not altering the study's conclusions. This demonstrates the robustness of the research results.

Table 8: Endogeneity Test Regression Results

Variable	Instrumental Variable Method (IV 2SLS)	
	(1) First Stage	(2) Second Stage
	RD Lagged 2 Periods	NP
Ln (Regional R&D Institutions)	0.0024*** (2.83)	
Regional Industrial Firm Scale	-0.0027** (-2.16)	
RD Lagged 2 Periods		10.0513*** (4.82)
LEV	-0.0105** (-1.98)	0.2124*** (4.14)
Time Fixed Effects	Yes	Yes
Constant	0.0308 (1.09)	-0.2333*** (-4.40)
R-squared	0.6704	0.5514
Observations	108	108
F-value	17.14 (0.0000)	
Kleibergen-Paap rk LM Statistic		24.514 (0.0000)
Hansen J Statistic		4.176 (0.1239)

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

3.6 Heterogeneity Analysis

In more economically developed regions, the concentration of R&D talent is higher, and R&D investment is greater, providing more significant support for the transformation of corporate profit models. To analyze this, the sample's average GDP from 2012 to 2019 was first calculated and then divided into two groups based on the median. The impact of R&D investment on profit model transformation was then examined. The regression results are shown in Table 9.

Table 9: Heterogeneity Test Results

Variable	Economically Developed Regions	Relatively Less Developed Regions
RD Lagged 2 Periods	3.861** (2.305)	3.005*** (3.679)
LEV	0.29*** (4.247)	0.166*** (3.253)
Time Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Constant	-0.079 (-2.166)**	-0.022 (-1.167)
Adj R^2.	0.265	0.233
Observations	54	54

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

Table 9 shows that R&D investment's impact on profit model transformation is stronger in more economically developed regions than in relatively less developed regions. This is likely due to the higher R&D investment in more economically developed areas.

4. Research Conclusions and Implications

4.1 Research Conclusions

By constructing a moderated mediation model with patent operation as the mediating variable and total factor productivity as the moderating variable, this study examined the impact of R&D investment on the transformation of profit models. The primary conclusions are as follows:

First, R&D investment is fundamental, and the level of patent operation plays a partial mediating role in the relationship between R&D investment and the transformation of profit models. The direct effect of R&D investment is relatively large, which is attributed to the presence of numerous dormant patents or the operation of firms using proprietary technology.

Second, within the R&D investment - patent operation - profit model transformation chain, total factor productivity can enhance the effect of patent operation on profit model transformation. However, it does not amplify the effect of R&D investment on patent operation levels, meaning that total factor productivity does not moderate the first half of the pathway but only the latter half. This may be due to the currently low level of total factor productivity, which is based on low human capital and technological equipment, thereby affecting the efficiency of high-quality patent output and, consequently, the level of patent operation. Total factor productivity is influenced by multiple factors, with the effect of R&D investment on total factor productivity exhibiting significant lag, which is beyond the scope of this study.

4.2 Theoretical Implications

First, to unlock the black box between R&D investment and corporate performance, research must follow the chain from R&D investment through patent operation to profit model transformation while also considering the role of proprietary technology. R&D investment can yield both patents and proprietary technologies, both of which are crucial intellectual property assets. By operating these intellectual property assets, firms can transition their technical assets from a static to a dynamic state, thereby increasing the proportion of intellectual property revenue.

Second, in addressing the black box problem of R&D investment output, it is advisable to downplay traditional metrics such as patent application numbers, grant numbers, citation counts, and citation frequency. Instead, emphasis should be placed on the patent implementation rate as a key indicator. This approach can help shift China from being a major patent producer to becoming a patent powerhouse.

4.3 Practical Implications

First, enhancing Patent Quality without Sacrificing quantity: the growth in patent numbers should not come at the expense of patent quality. High-quality patents should meet the current economic development needs and be nurtured for their legal value, strategic significance, existing market value, potential market value, and commercial value. Creating high-quality patents is a systemic effort. At the government level, measures include enhancing patent protection, establishing policy-driven intellectual property pledge insurance institutions, and improving intellectual property custody systems. At the firm level, the success of products, services, and commercial ventures depends on effectively managing fundamental intellectual property assets, particularly patents. Firms must integrate intellectual property management into their business processes and culture to fully develop, protect, and utilize these assets. Separation of responsibilities for different forms of intellectual property can lead to inefficiencies, thus necessitating a comprehensive intellectual property management plan that reduces mismatches. This plan should include:

Strategic Decision-Making: Elevating the formation and operation of intellectual property capital to the highest levels of corporate decision-making.

Policies and Systems: Implementing responsibility accounting systems to ensure accountability and alignment of intellectual property capital formation and operation with corporate goals.

Employees and Behavior: Encouraging full participation in intellectual property management, which is often hindered by a lack of incentives within the corporate culture and system.

Goals and Actions: Using continuous improvement methodologies such as PDCA cycles or balanced scorecards.

Management Processes: Employing comprehensive processes to manage knowledge, information, patents, and trademarks, ensuring knowledge is shared rather than just acquired and visualized.

High-quality patent implementation involves standardization, productization, commercialization, and capitalization. Beyond conventional patent protection measures, firms need to enhance government and market supervision mechanisms, regulate patent agency practices, and reform patent funding and performance evaluation policies. This includes integrating patent outcomes into scientific performance evaluations and ensuring rewards are based on patent transformation to prevent the proliferation of low-quality patents. Such policies are crucial not only for firm behavior but also for reforming scientific performance in academia. In summary, ensuring the effective implementation of patents through policy incentives and support at both government and firm levels is vital for unlocking the black box of R&D output.

Second, emphasizing the Role of Total Factor Productivity in Enhancing Patent Operation Levels: Total factor productivity (TFP) is a critical measure of technological progress, indicating that the same labor and capital inputs can yield higher outputs. Therefore, firms should align R&D investments with human capital and institutional innovations. From a human resources perspective, removing restrictions on job-related inventions and increasing tax incentives for converting job-related scientific achievements can maximize the impact of human capital on technological progress. In terms of fixed asset investments, enhancing the technological content of equipment can boost the role of innovative facilities in driving technological progress. From an institutional standpoint, improving the management and control of R&D investments can reduce inefficient R&D spending.

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