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High-Tech Accreditation, Technology Spillover, and Innovation

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Abstract

Innovation is the foundation of business survival. The two primary factors that impede enterprise innovation are funding limitations and technology spillover. China's continuous qualification recognition of high-tech enterprises provides financial subsidies to supported enterprises, thereby resolving a portion of the problem of financing constraints. This paper establishes the duopoly Cournot competition model and incorporates technology spillover into the research process of government subsidies and enterprise innovation R&D. It has been discovered that government subsidies can increase the innovation input of enterprises in proportion to the magnitude of the technology spillover effect and the marginal technology efficiency. In addition, utilizing China's A-share listed companies in Shandong Province from 2015 to 2021 as the research object, this paper develops a fixed-effect model to conduct an empirical test of the specific impact of high-tech enterprise qualification recognition in Shandong Province on enterprise innovation. The test results indicate that recognizing the qualifications of high-tech businesses is advantageous for boosting the innovation level of businesses. Nevertheless, this type of industrial policy has a more evident stimulative effect on catering innovation.

Keywords: high-tech accreditation, technology spillover, innovation, industrial policy

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1. Introduction

The mode of development of Chinese enterprises has shifted from expansion to innovation. To attain long-term development, the level of an enterprise's innovation, research, and development is its driving force and core competitiveness. It is also the inexhaustible force that propels a nation to advance its industrial structure. The Ministry of Science and Technology, the Ministry of Finance, and the State Administration of Taxation promulgated the "Measures for the Administration of the Identification of New and High-Tech Enterprises" in 2008 to promote mass entrepreneurship and innovation. Shandong's position as one of China's three most economically powerful provinces in terms of economic volume has a direct impact on the country's high-quality development. Jinan Municipal People's Government initiated the "Three-year Action Plan for the Cultivation of High-Tech Enterprises in Jinan" in accordance with the "Notice of Several Measures of

Shandong Provincial People's Government on the Construction of Innovation-Oriented Provinces" in order to further implement the innovation-driven development strategy and comprehensively promote the construction of innovation-oriented cities. The qualification of high-tech enterprises falls under the classification of selective industrial policy. As a result of the fact that selected enterprises can receive financial subsidies during the implementation of this policy, there will inevitably be enterprises that appeal to innovation, which will have a negative impact on the effectiveness of industrial policy. Therefore, it is of the utmost importance to investigate how the qualification recognition of high-tech enterprises affects the target enterprises and whether or not it effectively promotes the development of the level of substantive innovation within enterprises.

2. Literature Review

The SME sector is the primary driver of an innovation-driven strategy. However, enterprise innovation is a resource-dependent endeavor that necessitates long-term capital investment, a high degree of risk, and a lengthy cycle. There is a dearth of motivation for R&D and innovation in the majority of small and medium-sized enterprises and private companies (Berger & Udell, 1990). Internal and external resources are limited, and there is a lack of motivation for R&D. When internal cash flow is uncertain, it is typically difficult for businesses to increase the effectiveness of their use of funds. Due to the "precautionary motive", the capacity to adapt to changes in the external environment weakens, and enterprises adopt more conservative innovative R&D practices (Hall et al., 2005; Malherbe, 2014).

In order to encourage enterprise innovation, leverage the entire society and enterprises to increase R&D investment, and promote high-quality economic development, China has implemented a series of policies to alleviate the financial constraints faced by enterprises in R&D investment over the past few years. The recognition of high-tech enterprises is one of the most significant industrial policies. Individuals designated as high-tech enterprises are eligible for a number of financial subsidies from the federal, state, and municipal administrations. Simultaneously, the number of high-tech enterprises exhibits an exponential growth pattern. Nevertheless, a significant number of researchers have discovered that certain innovation incentive policies do not serve as incentives but rather hinder enterprise innovation and innovation performance (Boeing, 2016; Howell, 2017; Wei et al., 2017). This is primarily due to resource mismatch issues that may arise during the implementation of industrial policies.

In addition to the lack of necessary funds for innovation, a significant factor affecting the operations of the innovation enterprise is the impact of innovation externalities, also known as technology spillover. The spillover effect of technology refers to the fact that when an enterprise adopts new technology to carry out production and operation activities or carry out innovative R&D investment activities, it will not only produce the expected effects, such as indirectly reducing its own production cost, improving production efficiency, and expanding its own market share, but it will also have an impact on other organizations or society. Reducing the cost of innovation for other businesses or organizations, for instance, indicates that innovative R&D activities are susceptible to external spillovers. Even though imitation and reproduction of new technologies, new knowledge, and new processes are relatively inexpensive and efficient, the private benefits generated by innovative R&D are less than the social benefits. Therefore, there will be "market failure" if enterprise innovation activities rely solely on the market mechanism for sustenance. Exploring the relationship between spillover effect and R&D decisions by constructing various decision models is the prevalent practice at present. For instance, Liu and Huang (2019) developed a differential game model to examine the influence of spillover effects under various innovative R&D strategies of pharmaceutical companies.

In light of the previous research, we cannot ignore the question of whether the accreditation and recognition of high-tech enterprises contribute to the enterprises' actual innovation output. Considering technology spillover, what is the impact of industrial policy-driven government subsidies on enterprises? In-depth discussion of the aforementioned issues is useful for accurately evaluating the impact of such industrial policies and also has important reference value for the future improvement of high-tech industry identification policies.

3. The Model

Referring to d'Aspremont and Jacquemin (1988) description of the competitive game model of duopoly enterprises in R&D expenditure activities, this paper adopts the two-stage game model of enterprises: in the first stage, both enterprises choose R&D investment; in the second stage, the two sides of the game engage in Cournot competition and select their own optimal output. Regarding the government's choice of subsidy policies, decisions are made to maximize social welfare, i.e., to subsidies enterprises that conduct research and development activities and to determine the subsidy amount for enterprises.

3.1 Model Setting

Suppose that on a market dominated by oligopolies, there are two innovative, competitive enterprises that produce homogeneous and alternative products, and that these two organizations engage in Cournot competition (output competition). The enterprises' inverse linear demand function is:

$$p_i = a - bQ \tag{1}$$

Where p and q are the firm's selling price and output quantity, respectively. $Q=q_i+q_j$. b represents the substitution rate of the products of both parties in the game, satisfying the condition that $0<b<1$. The larger b is, the higher the substitution degree of the products of both parties is.

The initial marginal cost of production, denoted by c, is identical for both competitors. Businesses can reduce expenses by increasing innovation input, particularly process innovation. In other terms, R&D expenditures can be sustained by organizations. The R&D input is x. Due to the spillover effect of technology, a company can benefit from another company's R&D activities without paying the other company. The most evident advantage is a reduction in production costs. Following R&D activities, the actual marginal production cost of a business is as follows:

$$c_i = c - x_i - \beta x_{3-i} \tag{2}$$

Where β is the external R&D input spillover rate, which reflects the unidirectional technology spillover between enterprises. If the degree of information sharing between businesses is increased, there will be more exchange opportunities, technology and knowledge will spread more rapidly, the learning effect of businesses will be more pronounced, and the spillover rate will be higher. If β equals zero, the enterprise chooses not to cooperate, i.e., it conceals its actions, and the degree of patent technology protection is extremely high. Currently, the degree of collaboration between enterprises is at its lowest, and there is no technology spillover. If β equals 1, enterprises opt for cooperation, that is, comprehensive knowledge sharing. Currently, technology sharing alliances are formed between enterprises, information transmission and circulation, new technology and knowledge are shared to the greatest extent among enterprises, and technology spillover is at its peak, thereby avoiding repetitive research and development activities and reducing unnecessary expenses.

Taking into account the diminishing effect of R&D investment returns, innovation R&D investment costs are expressed in quadratic form: $\gamma x^2/2$, where γ represents marginal technical efficiency (Amir, 2000; Martin, 2002; Matsumura & Matsushima, 2004). The larger an organization is, the greater its innovation capability, the greater its unique technology output efficacy, and the more obvious its benefits.

Suppose that the government adopts the quota subsidy method for innovative products, and the subsidy amount for each new product is s.

Assume that the market is a fully informed market.

3.2 Cournot Model of Duopoly Competition

Because there is no innovation output when duopoly enterprises do not invest in innovation research and development, the government will not provide financial subsidies. The initial marginal cost of production in this instance remains at c. The maximization of profits guides the production and administration activities of duopoly businesses. Currently, the profit function of market-based enterprises is:

$$\pi_i = \left[a - bQ\right] q_i - c q_i \tag{3}$$

In market competition, enterprises utilize Cournot competition, and output quantity is determined by the maximization of profits principle. If the first-order partial derivative in (3) is equal to zero, the output quantity of the Nash-Cournot equilibrium for producers can be determined:

$$q_i^0 = \frac{(a-c)}{3b} \tag{4}$$

The equilibrium profit of duopoly enterprises without innovation R&D input is:

$$\pi_i^0 = \frac{1}{9b}(a-c)^2 \tag{5}$$

The equilibrium output of the entire market is equal to the aggregate of the outputs of the two oligopoly equilibria, so the Nash equilibrium output of the market as a whole is:

$$Q^0 = \frac{2(a-c)}{3b} \tag{6}$$

Therefore, the equilibrium output quantity, profit, and total market output of duopoly enterprises are lower the stronger the substitution between the products produced by duopoly enterprises.

3.3 Non-Cooperative Game Strategy

When determining output and R&D input, we then presume that enterprises choose to apply the non-cooperation game strategy. In this instance, the profit function of market-based enterprises is:

$$\pi_i = \left[a - bQ + s\right]q_i - \left[c - x_i - \beta x_j\right]q_i - \gamma\frac{x_i^2}{2} \tag{7}$$

Evidently, the profit expressed in Formula (7) is a function jointly determined by the output of the manufacturer, the unit price, the R&D input, and government subsidies. The yield at equilibrium is calculated as:

$$q_i^* = \frac{(a-c+s)+(2-\beta)x_i+(2\beta-1)x_j}{3b} \tag{8}$$

The profit at equilibrium is calculated as:

$$\pi_i^* = \frac{1}{9b}\left[(a-c+s)+(2-\beta)x_i+(2\beta-1)x_j\right]^2 - \gamma\frac{x_i^2}{2} \tag{9}$$

Where we can find a unique solution for x:

$$x_i = \frac{(2-\beta)\left[a-c+s+(2\beta-1)x_j\right]}{4.5b\gamma-(2-\beta)^2} \tag{10}$$

When $0.5<\beta<1$, it indicates that technological diffusion is strong at this time. Then, the cost changes caused by the increase and decrease of R&D input of both parties change in the same direction, because in this case, both parties share technical knowledge resources to a greater extent and can benefit from the cost savings brought about by the other party's R&D input. Therefore, when one party increases R&D expenditure, the significant technology spillover can reduce the cost of the other party's enterprise, thereby encouraging the other party's R&D expenditure. When $0<\beta<0.5$, it indicates that the technological spillover is negligible. Then, the cost change caused by the increase or decrease in R&D input by both competing businesses is reversed.

Considering the solution's symmetry, Equation (6) can be rearranged into Equation (7). Consequently, the optimal R&D input for firms in a non-cooperative R&D game is:

$$x^* = \frac{(a-c+s)(2-\beta)}{4.5b\gamma-(2-\beta)(1+\beta)} \tag{11}$$

In other words, the R&D input of one party cannot reduce the cost of the other party when businesses choose to safeguard their unique technologies and intellectual property rights vigorously. The innovation research and development of one party cannot promote the research and development investment of the other party through cost-saving channels.

The equilibrium output of the entire market is equal to the aggregate of the outputs of the two oligopoly equilibria, so the Nash equilibrium output of the market is:

$$Q^* = \frac{2(a-c+s)}{3b}\left[\frac{4.5\gamma}{4.5b\gamma-(2-\beta)(1+\beta)}\right] \tag{12}$$

By contrasting the equilibrium results for enterprises before and after R&D activities, it is evident that after R&D innovation input, enterprises receive government subsidies due to the reduction in production costs. In addition, due to the transfer of technology, the R&D expenditures of other businesses reduce their own expenses. Therefore, the optimal output quantity, equilibrium profit, and equilibrium total output of the market are all greater with innovation activities than without them. If the government increases innovation R&D subsidies and an enterprise implements a two-stage non-cooperative game strategy, it will improve the enterprise's balanced R&D input level and help the enterprise reduce costs. If the technology spillover is robust at this time, other enterprises will benefit from this cost reduction advantage. Concurrently, the increase in government subsidies will also enhance the market's equilibrium output. After obtaining the enterprise's equilibrium result, further consideration is given to the government's decision option. In accordance with the maximization of social welfare principle, the government provides quota subsidies for innovation research and development.

It is used to demonstrate the level of social welfare. Social welfare equals the sum of consumer surplus and corporate earnings minus government transfer payments. If consumer surplus is expressed in the form of quadratic market capacity based on the practice of (Dixit & Stiglitz, 1977), then the exact expression of social welfare *SW* is as follows:

$$SW = \frac{1}{2}b(q_i + q_j)^2 + \pi_i + \pi_j - s(q_i + q_j) \tag{13}$$

The optimal solution for *s* is:

$$s^c = \frac{(a-c)\left[4.5b\gamma - (2-\beta)(1-5\beta)\right]}{9b\gamma - 2(2-\beta)(1+4\beta)} \tag{14}$$

The optimal government subsidy's derivative to the spillover coefficient is greater than 0, indicating that the optimal innovation subsidy rises as technology spillover improves. On the one hand, government subsidies can compensate for the negative externalities caused by technology spillover for R&D enterprises; on the other hand, when technology spillover is strong, the R&D activities of an enterprise can reduce the enterprise's costs, thereby generating motivation and resources for innovation and R&D. This technology spillover resulting from the overall reduction in production costs is augmentative. Consequently, government subsidies promote enterprise innovation.

4. Empirical Analysis

4.1 Data

According to the aforementioned theoretical model, government subsidies resulting from the accreditation of high-tech enterprises are conducive to enterprise innovation. Then, specifically, does this innovation serve innovation or is it substantive? To address the aforementioned issues, the study data set comprises samples of 294 Chinese A-share listed enterprises located in Shandong Province from 2015 to 2021. CSMAR database for patent data of listed companies; Wind database for other financial data.

4.2 Variable Definition

The cumulative number of patents obtained at the end of each year and the total R&D expenditure are used as proxies for enterprise innovation in this paper. Since utility model patents and appearance patents are easier to obtain than invention patents, we use the total number of utility model patents and appearance patents obtained annually as proxies for strategic innovation and the total number of invention patents obtained annually as a proxy for substantive innovation. As the primary explanatory variable, we consider whether the enterprise obtains the high-tech enterprise certification this year. In addition, it regulates other financial factors that can influence enterprise innovation. Refer to Table 1 for specific variable methods.

Table 1. Variable Definition

Variable	Variable Symbol	Variable Definition
Dependent Variables	*Patents*	The cumulative number of patents granted at the end of a given year
	Invention	The cumulative number of invention patents obtained by the end of a given year
	Utility	The cumulative number of utility model patents obtained by the end of a given year
	Design	The cumulative number of design patents obtained by the end of a given year
	Strategy	The cumulative number of appearance patents obtained by the end of a given year

Independent Variable	*Qualified*	If a company has acquired the qualification of a high-tech enterprise in a given year, a value of 1 is assigned; otherwise, a value of 0 is assigned.
Control Variables	*Asset*	The natural log of 1 plus the total assets of the enterprise.
	Age	The period that the enterprise has been listed.
	Leverage	The asset-liability ratio of the enterprise.
	Operate	Annual growth rate of operating revenue.
	RD	Research and development expenditure in RMB.
	Hold	Shareholding ratio of the largest shareholder.
	Fix	Ratio of net fixed assets to total assets.
	Netprofit	Net profit (in hundred million yuan)
	Opercash	Ratio of net operating cash flow to operating income.

In this paper, the fixed effect model is employed to examine the impact of high-tech enterprise accreditation recognition on enterprise innovation. The model's precise expression is as follows:

$$DependentVariables_{i,t} = \alpha_0 + \beta_1 Qualified_{i,t} + Controls_{i,t} + year_t + \varepsilon_{i,t} \tag{15}$$

4.3 Summary Statistics

Table 2 displays the basic statistical characteristics of significant variables. From 2015 to 2021, more than fifty percent of the listed companies in Shandong Province will be accredited as high-tech enterprises. The innovation levels of listed companies in Shandong Province vary considerably. As an illustration, the utmost value of total enterprise innovation is 7107, whereas the minimum value is only 1. Moreover, the statistical characteristics of other financial indicators reveal that the leverage level, profitability, and capital status of publicly traded companies vary.

Table 2. Summary Statistics

Variable	Mean	Median	SD	Max	Min
Qualified	0.616	1.000	0.487	1.000	0.000
Patents	184.636	52.500	522.631	7107.000	1.000
Invention	59.313	13.000	246.242	3141.000	0.000
Utility	70.416	21.000	177.636	1710.000	0.000
Design	15.199	1.000	37.646	215.000	0.000
Strategy	103.152	32.000	242.932	1920.000	0.000
Asset	3.481	3.364	1.455	8.561	0.394
Age	2.097	2.303	0.945	3.401	0.000
Leverage	41.507	39.189	20.760	193.803	1.956
Operate	104.089	38.771	529.214	10644.458	-97.626
RD	1.745	0.447	6.073	89.666	0.000
Hold	35.534	32.030	17.065	100.000	4.150
Fix	0.237	0.221	0.156	0.880	0.000
Netprofit	4.381	1.055	14.644	250.394	-67.542
Opercash	-3.727	9.800	505.601	824.460	-21614.820

4.4 Empirical Analysis Result

In this paper, firm innovation, firm R&D

expenditure, firm invention innovation, and firm catering strategy innovation are used as explanatory variables to conduct regression analysis on the model. The estimates of panel regression with time-fixed effects are provided. In panel regression, we calculate firm-cluster standard errors.

The regression results of Table 3 indicate that recognizing high-tech qualified enterprises has a significant effect on enterprise innovation. In particular, the marginal impact of qualification recognition on the total innovation of high-tech enterprises is 0.784 and the marginal impact on R&D expenditures is 1.236, both of which are significant at the 10% and 5% significance levels, respectively. The results in columns (3) and (4) of the table indicate, however, that this industrial policy primarily promotes the strategic innovation of businesses. Although the marginal impact on enterprise invention and innovation is economically significant and the regression coefficient reaches 28,981, the significance is not statistically significant.

Table 3. High-tech Enterprise Qualification Accreditation and enterprise Innovation

Variables	(1) *Patents*	(2) *RD*	(3) *Invention*	(4) *Strategy*
Qualified	0.784*	1.236**	28.981	0.742*
	(0.942)	(0.558)	(20.110)	(0.860)
Asset	-0.129	0.011*	0.321	0.328
	(0.196)	(0.006)	(0.381)	(0.619)
Leverage	4.156**	0.005	0.418	3.378
	(1.998)	(0.015)	(0.540)	(2.065)
Operate	-0.034*	-0.000	-0.003	-0.072
	(0.018)	(0.000)	(0.004)	(0.094)
Netprofit	6.077	0.142**	1.633	5.927
	(4.758)	(0.063)	(2.017)	(6.950)
Opercash	0.894	-0.017	0.044	-0.024
	(0.685)	(0.011)	(0.302)	(0.515)
Fix	-253.500	-2.578	-14.640	-579.051
	(201.547)	(1.688)	(78.350)	(351.867)
Hold	-3.246	-0.056**	-1.788	4.677
	(3.991)	(0.024)	(1.579)	(4.120)
Age	20.090	-0.163	-7.061	50.636
	(26.173)	(0.278)	(11.610)	(42.953)
Cons	71.301	1.851	66.068	-195.597
	(149.008)	(1.330)	(41.672)	(185.556)
Time Fixed	YES			
N	531	1271	485	210
Adj R^2	0.027	0.575	0.073	0.175

Note: *, **, and *** represent the significance levels of 10%, 5%, and 1%, respectively.

5. Conclusions

In this paper, a duopoly Cournot competition model is established based on the government subsidies brought about by the qualification recognition of high-tech enterprises, and technology spillover is incorporated into the research process of government subsidies and enterprise innovation research and development.

When the technology spillover effect is stronger and marginal technical efficiency is greater, it has been discovered that government subsidies can increase the innovation input of businesses. Moreover, given that Shandong Province, as China's economic powerhouse, is at the vanguard of innovation-driven economic development, the province's innovation outcomes are highly significant for the future of high-quality economic development. Utilizing China's A-share listed companies in Shandong Province from 2015 to 2021 as the research object, this paper develops a fixed-effect model to empirically assess the impact of high-tech enterprise qualification recognition on enterprise innovation in Shandong Province. The test results indicate that recognizing the qualifications of high-tech businesses can increase their innovation level. Nonetheless, the incentive effect of this industrial policy on hospitality innovation is more pronounced because high-tech businesses will receive a substantial number of financial subsidies.

On the basis of the preceding conclusions, we believe that as the vanguard of the implementation of an innovation-driven strategy, high-tech companies should undertake the crucial responsibility of constructing an innovation-driven province. In light of the recognition that high-tech enterprises can increase the innovation level of enterprises, strengthening the cultivation and incubation of high-tech companies is essential. In this process, however, prioritizing the development of the quality of high-tech companies is needed. Blindly purchasing the number of high-tech enterprises will further create the illusion of innovation and exacerbate the "patent bubble." It is not conducive to the qualitative development of the regional or national economy over the long term.

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