Technological Lock-in and Enterprise Breakthrough Innovation

——the Moderating Role of Innovation Inertia and Intellectual Property Protection

Yiting Hu, Tianran Wang*, and Hailan Sa

School of Economics and Management, Shihezi University, Shihezi, China

*Corresponding author: 278255318@qq.com

Abstract. Based on the patent application panel data from Chinese listed companies involved in 28 industrial industries from 2009 to 2017, this paper examines the impact of technological lock-in on enterprise breakthrough innovation, as well as the moderating role of innovation inertia and intellectual property protection using multiple regression, grouping regression, and lag models. According to the findings, technological lock-in has a significant negative impact on enterprise breakthrough innovation. Furthermore, innovation inertia serves as a positive moderator, whereas intellectual property protection serves as a negative moderator between technological lock-in and enterprise breakthrough innovation. The findings are critical for China's implementation of the innovation-driven strategy and promotion of high-quality economic development.

Keywords: Technological Lock-in; Breakthrough Innovation; Innovation Inertia; Intellectual Property Protection

1 Introduction

In the era of digitalization and informatization, China has strengthened its support for 'Mass Entrepreneurship and Innovation' to improve the leadership positions of innovative enterprises. As a pioneer in the high-tech industry, the computer, communication, and other electronic equipment manufacturing industry is known for its high efficiency of the invention and has been at the forefront of the world in terms of patent applications. However, challenges such as lightweight patents and core technology neck sticking indicate that the enterprises' breakthrough innovation potential still has to be strengthened [1]. According to the technology track theory, technological lock-in raises the cost of technology conversion, leads to the formation of an inefficient technology market, and obstructs the diffusion of optimal technology, causing the technology market to fall behind in terms of competition and innovation [2].

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'Technology lock-in' was first proposed by David [3]. Arthur pointed out that technological lock-in is a technology market imbalance caused by the leading technology system's self-strengthening tendency, which stifles enterprises' breakthrough innovation [2]. Because it represents a significant alteration to the existing technology system [4], the development of breakthrough innovation is fraught with dual uncertainties: firstly, the uncertainty of innovation driving force results, demonstrating that the disparity in enterprise innovation inertia causes heterogeneous feedback on innovation driving force [5]; secondly, the result of innovation transformation is uncertain, implying that the ineffective intellectual property protection system and the externality of technology spillover blur the expected benefits of breakthrough innovation [6]. In the technological lock-in environment, the uniqueness of breakthrough innovation necessitates more stringent requirements for enterprises to prevent innovation inertia and for the government to improve intellectual property protection. Exploring the relationship between technological lock-in and enterprise breakthrough innovation is critical for enhancing enterprise innovation capability, particularly in the computer sector, which places a premium on breakthrough innovation.

This paper will first use the DEA-SBM model to measure technological lock-in in various industrial industries, then investigate the impact of technological lock-in on enterprise breakthrough innovation from the innovation-driven perspective of pursuing advantages and avoiding disadvantages and the moderating role of innovation inertia and intellectual property protection between them.

2 Theoretical Analysis

2.1 Analysis on the Impact of Technological Lock-in on Enterprise Breakthrough Innovation

Pursuing advantages: To maximize earnings in a technological lock-in environment, enterprises prefer to stick with the present technology system rather than actively pursue breakthrough innovation [7]. According to dynamic competition theory, when peer firms as a whole have a low level of innovation, enterprises will interpret technological market disadvantages and risks more discreetly, and approach the same degree of innovation eventually [8,9]. Furthermore, the degree of technological lock-in is proportional to the network effect of the technology system [10]. The technology standard mastering enterprises will continue to raise the technology acquisition cost of rival enterprises as the size of the network effect expands to generate consistent excess profits from the technology system [11].

Avoiding disadvantages: According to the theory of planned behavior, individual behavior and willingness to generate conduct are influenced by experience and expectation (perceptual behavior control). Technological lock-in heightens the uncertainties surrounding the transformation of innovation outcomes, which decreases the likelihood of new technology adoption. Besides, the individual's behavior and willingness to generate conduct are also influenced by their perception of pressure (subjective normative pressure). One of the causes of technological lock-in is institutional lock-in, implying that the lack of relative normative legitimacy and cognitive legitimacy stymies makes the development of enterprises' breakthrough innovation subjected to intense subjective normative pressure [12]. As a result, technology spillover is difficult to manage, and ‘free-riding’ becomes an issue [13].

H1: Technological lock-in has a significant negative impact on enterprise breakthrough innovation.

2.2 Analysis on the Moderating Role of Innovation Inertia

Enterprise satisfied with the low-level pursuit of innovation and overlooking the high-level pursuit of innovation is said to be enduring innovation inertia [14]. Positive innovation inertia can be seen commonly in enterprises mastering the leading technology standard, which forces the company to keep making incremental improvements to the inefficient technology system that dominates the technology market to maintain its technological market position. Ordinary enterprises usually suffer from passive innovation inertia which results in a lack of innovation impulse [15]. According to the organizational life cycle theory, during the growth period, enterprises may actively explore technology research to pursue efficient development [16]. While in the mature period, the high technology conversion cost formed by early technology investment and current technology dependence further reduces the expectation of new technology adaptation of enterprises, and finally inhibits their breakthrough innovations [17].

H2: Innovation inertia acts as a positive moderator between technological lock-in and enterprise breakthrough innovation.

2.3 Analysis on the Moderating Role of Intellectual Property Protection

Intellectual property protection is a useful institutional system for ensuring the unique source of revenue for enterprise innovation [5]. Intellectual property protection can provide visible expected benefits to breakthrough innovation, effectively mitigate the externality of technological spillover, and raise the normative and cognitive legitimacy thresholds of enterprises, particularly innovative imitation enterprises. When intellectual property protection is weak, the externality of breakthrough innovation’s technological spillover cannot be rectified due to the cheap violation cost [18]. The expected income from breakthrough innovation is uncertain and finally lowers the new technology adoption of enterprises.

H3: The negative impact of technological lock-in on enterprise breakthrough innovation has been decreased as intellectual property protection has improved.

3 Materials and Methods

Using data from CSMAR, China Science and Technology Statistical Yearbook, and China Statistical Yearbook. After excluding samples with a serious lack of key data, the patent application panel data of Chinese listed companies involved in 28 industrial industries from 2009 to 2017 is established. All continuous variables are decreased by 0.01 and 0.99 quantiles to reduce the impact of extreme outliers on the regression findings.

1) Enterprise Breakthrough Innovation: Invention patents are used as a proxy variable for corporate breakthrough innovation based on established research practice [19].

2) Technological Lock-in: The technological lock-in in diverse industries is measured using the DEA-SBM model through MaxDEA, based on established research practice [20]. R&D internal funds and R&D employees full-time equivalent are chosen as investment indices. The number of patent applications accepted and new product sales are chosen as output indicators. Each industry's technological lock-in is calculated by subtracting the value of the industry's technological innovation efficiency from 1.

3) Innovation Inertia: The ratio of the number of appearance new type patent applications to the total number of patent applications is recognized as a proxy variable of innovation inertia, according to previous research practice [14].

4) Intellectual property protection: The ratio of turnover of the technology market in the region where the sample companies are located to total GDP is split into three groups (weak, medium, and strong) based on the principle of three equal points according to established research practice [11].

5) Control Variables: Based on resource-based perspective theory and stakeholder theory, the logarithm of enterprise's age, R & D, Tobin-Q, government subsidies, senior executives, and independent directors are chosen.

The following models are created to test the previous hypothesis through Stata 16.0:

$$BI_{i,t}(BI_{i,t+1}, BI_{i,t+2}) = \alpha_1 + \alpha_2 LI + \sum \alpha_j Contro\,l_{i,t} + \varepsilon_{i,t} \tag{1}$$

$$BI_{i,t}(BI_{i,t+1}, BI_{i,t+2}) = \beta_1 + \beta_2 LI + \beta_3 LI \times II + \sum \beta_j Contro\,l_{i,t} + \varepsilon_{i,t} \tag{2}$$

In these models, i and t refer to the observation samples and time. Enterprise breakthrough innovation is BI, technological lock-in is LI, innovation inertia is II, and control variables are Control. Equation (1) is used to see how technological lock-in affects enterprise breakthrough innovation. Equation (2) is used to see if innovation inertia has a moderating function between technological lock-in and enterprise breakthrough innovation. Given the possibility of a time lag in the breakthrough innovation and patent application, the regression results for lag periods 1-2 are examined further.

Due to the diverse geographical characteristics of intellectual property protection, the moderating function of intellectual property protection (IP) will be evaluated by grouping regression based on established research practice [11].

4 Results and Discussion

4.1 Descriptive Statistics and Correlation Analysis

The results of descriptive statistics are shown in Table 1. A total of 18 of the 28 industrial industries, accounting for 64.29%, exhibit a decreasing trend of technological lock-in. It should be noted that, although the degree of technological lock-in in the computer, communication, and other electronic equipment manufacturing industry has shown a relatively stable downward trend over the past decade, the reduction range has been low in the last 3 years.

4.2 The Negative Impact of Technological Lock-in

The regression results of technological lock-in and enterprise breakthrough innovation are shown in Table 2. The influence coefficients of technological lock-in on enterprise breakthrough innovation are strongly negative at the 1% and 5% levels, implying that technological lock-in has a significant negative impact on enterprise breakthrough innovation. Furthermore, the detrimental impact of technology lock-in on enterprise breakthrough innovation has a time lag, which is constantly increasing.

4.3 The Moderating Role of Innovation Inertia

The regression results of the moderating role of innovation inertia are shown in Table 3. The interaction coefficient of technological lock-in and innovation inertia in the current period and lag 1-period models is significantly negative at the levels of 5% and 10%, indicating that innovation inertia serves as a positive moderator between technological lock-in and enterprise breakthrough innovation. In addition, the moderating effect of innovation inertia also has a time lag.

4.4 The Moderating Role of Intellectual Property Protection

The regression results of the moderating role of intellectual property protection are shown in Tables 4, 5, and 6. Compared to Table 2, it can be concluded that the negative impact of technological lock-in on enterprise breakthrough innovation is decreasing in each intellectual property protection group. These results indicate that intellectual property protection negative moderator between technological lock-in and enterprise breakthrough innovation.

4.5 Robustness Check

The results of the robustness check are shown in Tables 7 and 8. Due to the number of patent applications (logarithm) is a typical left merging constrained variable. The Tobit model is used to examine the robustness of the current model's empirical results rather than other models based on existing methodological approaches [21]. The following are the reasons: firstly, it can alleviate the endogenous problem to some extent; secondly, based on previous experience, the current model's fitting degree is the best in most regression test results. The robustness test results are consistent with the previous text, which proves the research conclusions are robust.

Table 1. Descriptive Statistics

Definition of Var	Min	Max	Mean	SD	Obs
Breakthrough Innovation (BI)	0	5.861	1.804	1.206	9154
Technological Lock-in (LI)	0	0.766	0.307	0.225	8627

Innovation Inertia (II)	0	0.402	0.025	0.059	9149
Intellectual Property Protection (IP)	1	3	2.085	0.751	9246
Enterprise Age (Age)	0.223	3.925	2.645	0.406	7403
R&D (RD)	0	76.35	4.007	4.388	7403
Tobin-Q(Q)	0	30.241	2.392	2.037	7403
Government Subsidies (Gov)	0.320	0.947	0.737	0.060	6967
Executive Incentives (EI)	1.099	3.989	2.777	0.216	9241

Table 2. the Impact of Technological Lock-in

	BI_t	BI_{t+1}	BI_{t+2}
LI	-0.146**	-0.335***	-0.400***
	(-2.15)	(-4.33)	(-4.78)
Age	0.158***	0.226***	0.224***
	(4.40)	(5.13)	(4.30)
R&D	0.048***	0.042***	0.041
	(13.90)	(11.43)	(9.98)
Gov	3.448***	3.316***	3.211***
	(14.09)	(12.14)	(10.69)
EI	1.115***	1.136***	1.108***
	(15.85)	(14.22)	(12.57)
Tobin-Q	-0.037***	-0.035***	-0.038***
	(-5.11)	(-3.81)	(-3.73)
Cons_	-4.246***	-4.277***	-12.686***
	(-15.94)	(-14.15)	(-12.39)
N	6530	5004	4102
F	127.80	99.53	79.70

Table 3. the Moderating Role of Innovation Inertia

	BI_t	BI_{t+1}	BI_{t+2}
LI	-0.163**	-0.343***	-0.401***
	(-2.45)	(-4.47)	(-4.83)
II	-4.148***	-3.239***	-3.195***
	(-17.29)	(-11.29)	(-9.92)
LI×II	2.361**	2.156*	0.416
	(2.34)	(1.78)	(0.32)
Controls	√	√	√
N	6467	4970	4073
F	135.20	92.88	72.75

Table 4. Weak Intellectual Property Protection

	BI_t	BI_{t+1}	BI_{t+2}
LI	0.002	-0.242*	-0.323*
	(0.01)	(-1.90)	(-1.83)
Controls	√	√	√
N	1390	1069	872
F	25.68	18.29	15.33

Table 5. Mediunm Intellectual Property Protection

	BI_t	BI_{t+1}	BI_{t+2}
LI	-0.069	-0.229	-0.362***
	(-0.64)	(-1.44)	(-2.84)
Controls	√	√	√
N	2701	2100	1720
F	63.49	53.69	46.26

Table 6. Strong Intellectual Property Protection

	BI_t	BI_{t+1}	BI_{t+2}
LI	0.090	-0.110	-0.113
	(0.84)	(-0.91)	(-0.87)
Controls	√	√	√
N	2006	1529	1263
F	45.87	39.12	28.08

Table 7. the Robustness Check for H1 and H2

	H1	H2
LI	-0.134***	-0.050
	(-5.12)	(-0.73)
II		-4.150***
		(-17.00)
LI×II		2.314***
		(2.24)
Controls	√	√
N	6097	6039
Pseudo R^2	0.0862	0.0501

Table 8. the Robustness Check for H3

	Weak	Medium	Strong
LI	-0.123***	-0.069	0.090
	(-1.83)	(-0.62)	(0.83)
Controls	√	√	√
N	1390	2701	2006
Pseudo R^2	0.0862	0.0383	0.0476

5 Conclusions

This research examines the impact of technological lock-in on enterprise breakthrough innovation, analyses the moderating role of innovation inertia and intellectual property protection, and arrives at the following conclusions: firstly, technological lock-in has a significant negative impact on enterprise breakthrough innovation, with the negative impact increasing constantly; secondly, innovation inertia and intellectual property moderate the relationship between technological lock-in and enterprise breakthrough innovation. Furthermore, innovation inertia can compound the detrimental impact of technical lock-in on enterprise breakthrough innovation, while intellectual property protection has the opposite moderating role and function.

The following are the enlightenments of the study. To begin with, ordinary businesses should avoid short-sighted behavior and actively engage in scientific and technological innovation interactions to cultivate future core competitiveness; enterprises mastering the technical standards should actively open up new technological tracks to maximize their resource advantages. Next, depending on the heterogeneity of technological lock-in on industry technology development guidance, the government should scientifically take a variety of measures. Finally, the government should guarantee timely and dependable intellectual property certification and strict intellectual property protection for industry-developed knowledge.

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