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Technological Acquisition, Independent Research, and Enterprise Innovation Performance: Evidence from China

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Abstract

Some decision-making questions about innovation strategies need to be addressed in order to improve the innovation performance of corporate enterprises via independent research and technological acquisition. We select acquisition events of listed companies in China and analyze the impact of technological acquisition on their innovation output performance. The results show that technological acquisitions and independent research and development (R&D) promote innovation performance, and enterprises can expand this promotion channel through continuous innovation investment to enhance their own innovation efficiency. Unlike previous studies, the acquirer improves its innovation efficiency leading to the siphon effect, and the efficiency mediator reduces independent research in the short term and replaces technological acquisition to improve innovation. The technological overlap within acquisition significantly impacts innovation performance in the short term, but has a negative effect in the long term. There are also some mitigating effects between the technological overlap and technological efficiency.

Keywords: Technological acquisition; Independent R&D; Innovation efficiency; Innovation performance; China.

JEL: G34; O32; M41

1. Introduction

Technological innovation has increasingly become the core source of competitiveness for the survival and development of enterprises. In addition to innovation based on enterprises' independent research and development (R&D), technological acquisition is a proven means of adapting to the changing business models and quickly acquiring innovative resources needed to realize technological breakthroughs (Ahuja and Katila, 2001). As an acquisition enables enterprises to obtain technological resources from external sources, they will thus be properly poised to eliminate limitations currently imposed by existing resources or knowledge and either efficiently innovate or quickly access new fields of technology (Yu and Wang, 2008). According to WIND data, the aggregate value of merger and acquisition (M&A) transactions in China surged from RMB4.7 trillion in 2009 to RMB14.4 trillion in 2018. As there are increasing numbers of corporate acquisitions and reorganizations, research on technological acquisitions of enterprises and their subsequent innovation performance enhancement is of particular relevance for this second biggest economy in the world.

This purpose of this paper to investigate the impacts of technological acquisition and independent research on innovation output performance of corporate enterprises and to examine the moderating effect of innovation efficiency. There is “hypothesis of independent R&D” that indicate the sources of enterprises' internal technological innovation (Seru, 2014). Independent R&D within an enterprise improved absorbing ability, an ability to identify the quality of acquisition targets, accurate pricing, effective integration of technological resources, and production economies of scale (Phillips & Zhdanov, 2013). Independent R&D entails a series of measures and actions adopted by enterprises to improve their independent innovation ability in the course of their own corporate development. R&D requires a massive input of manpower, capital, and equipment. Indeed, technological innovation brought about by independent R&D investment of enterprises exhibits diminishing marginal returns (Bernstein, 2015). With economic growth, enterprises start to divert the focus of technological innovation away from internal R&D to technological acquisition. Therefore, M&A-style innovation has gradually revealed a certain degree of influence (Sevilir and Tian, 2012).

According to the hypothesis of “technological acquisition”, technological resources or elements are obtained from acquisition targets in order to enhance the capacity for technological innovation and competitiveness of the lead acquirers (Ahuja and Katila, 2001). This process often involves a transfer of property rights. Technological acquisition acts as a double-edged sword. On the one hand, it may increase the benefits of innovation by reducing innovation costs and risks. On the other hand, it is likely to swell organizational costs and lead to lower innovation efficiency (Zhao, 2009). Debates over the Innovation Theory of Harm and the Innovation Theory amongst researchers have existed for a long time (Chen and Zhang, 2019). The general consensus is that technological acquisition can help lead acquirers boost their innovation effects. Firms with larger innovation performance and R&D investments receive more bids and are more likely to be acquired (Wu and Chung, 2019). However, opinions are divided about the specific function of the enhancement mechanisms. It is highly anticipated that research and analysis can be conducted from the innovation of lead acquirers.

Along with the rapid development of China's economy, the increasing number of M&A events has provided a growing body of research samples. First, this research focuses on the M&As of Chinese enterprises and their subsequent innovation performance to analyze the impact of technological acquisition and independent R&D on the post-acquisition innovation performance of lead acquirers. Such an impact has some lag effects after acquisitions. In other words, the impact on innovation output diminishes after different time spans following an acquisition. Second, the sample data used in empirical studies demonstrate in recent years that those listed companies who have chosen technological acquisition as a means of technological innovation have also seen their original innovation efficiency undermined, thereby denting their innovation performance. Finally, the technological overlap between the acquirer and acquiree could exert a negative impact after technological acquisition. To be specific, such overlap is beneficial to independent R&D in the short term, but dilutes innovation efficiency in the long term.

This paper makes three contributions. First, considering that technological acquisition and many other factors may produce some lag effects, we use the evolution of corporate innovation performance rather than financial performance to indicate the innovation results that enterprises achieve through technological acquisition. Therefore, a three-year window period is set up to test the evolution of innovation. Second, lead acquirers must take into account their own innovation efficiency, which could exert a stronger moderating effect on innovation than R&D efforts and acquisitions. The original innovation efficiency of enterprises may offset the desired effects of technological acquisition and independent R&D endeavors. Innovation efficiency has a certain level of siphon effect on the innovation results achieved by independent R&D and M&As. Third, the technological overlap between the acquirer and acquiree could harm the innovation efficiency of enterprises with regards to dual moderating effects, since it has a dilution effect. This paper also considers the influence of technological acquisition on an enterprise's innovation efficiency.

The remaining parts of this paper are organized as follows: (2) literature review and hypotheses' development; (3) sample variables and data; (4) regression results and analysis; and (5) conclusions and implications.

2. Literature review and hypotheses' development

The motivation hypothesis of technological acquisition believes that a technological acquisition often occurs between two enterprises with different organizational characteristics. Furthermore, technological acquisition events typically occur between well-funded large enterprises (the acquirers) and technology-intensive small- and medium-sized enterprises (SMEs) (the acquirees). Fully-fledged large enterprises can alleviate their development dilemma caused by a decline in innovation efficiency by acquiring tech-intensive small enterprises (Sevilir and Tian, 2012). Small- and medium-sized startups, on the other hand, are likely to provide new sources of technology and knowledge for ground-breaking innovation. Therefore, big enterprises are willing to absorb and internalize their potential for technological innovation (Anderson and Xiao, 2016).

Both exogenous technological acquisition and endogenous R&D capabilities could impact an enterprise's innovation. Those enterprises with a strong innovation capacity generally act as the acquirer to merge with those enterprises weak at innovation. Bena and Li (2014) found that lead acquirers with stronger innovation capabilities and larger numbers of patents tend to produce fairly high innovation efficiency with relatively limited R&D investment. Contrastingly, those enterprises with fewer patents and heavy investments in internal R&D often become acquisition targets. However, Zhou et al. (2016) concluded that lead acquirers under technological acquisition are relatively weak at innovation. It is inevitable that lead acquirers of technological acquisition will see their innovation system suffer from technical shocks. The priority of mature lead acquirers in their product chains is to transform technologies into economic value and promote them in the market, while emerging, tech-intensive SMEs rely more on original innovation or technological breakthroughs. Therefore, this paper primarily discusses how technological acquisition and independent R&D affect an enterprise's post-acquisition innovation efficiency.

This research differs from previous studies. Unlike Bena and Li (2014), we consider the moderate effect of a firm's innovation efficiency. Ahuja and Katila (2001) focused on technological acquisition, but ignored R&D. We also differ from Sevilir and Tian (2012), Chen and Zhang (2019), Haucap et al. (2019) as they did not examine R&D and efficiency.

2.1 Impact of independent R&D and technological acquisition on innovation performance

Independent R&D input within an enterprise constitutes an important part of its innovation resources. The independent R&D intensity of a lead acquirer can be measured by the amount of R&D expenditures and the ratio of R&D expenditures to total assets, or the ratio of the two figures' natural logarithms. Ziedonis and Benson (2009) observed that an increase in internal R&D investment by a lead acquirer could boost its knowledge absorbing ability, thus being able to better spot high-quality acquisition targets, devising accurate pricing policies, integrating technological resources after M&As, and efficiently producing economies of scale. The R&D investment intensity of a lead acquirer also reflects its dependence on technological innovation activities and its attitude towards innovation. The higher such intensity is, the more the post-acquisition innovation performance will grow. Greater capital and manpower invested by a lead acquirer in technological innovation will make the enterprise more appealing to an acquiree, thus enhancing the possibility that the technological acquisition succeeds and enabling the two sides to cooperate smoothly following the M&A deal.

Investing in innovative R&D activities and shoring up knowledge absorbing ability are key to an enterprise maintaining its own innovation capabilities (Seru, 2014). The massive inputs in innovation could place considerable emphasis on innovation activities and foster a corporate culture where independent innovation is highly valued. On this premise, the lead acquirer of a technological acquisition can better absorb and internalize the technological resources obtained externally. The larger the innovation performance and R&D investments are, the greater is the number of acquisition bids received (Wu and Chung, 2019). Therefore, technological acquisition can improve the post-acquisition innovation performance of the lead acquirer to a greater extent. These considerations lead to the following hypothesis.

H1: The greater the independent R&D intensity is of two enterprises in an acquisition transaction, the higher is the subsequent innovation performance of the lead acquirer.

Technological acquisition has varying effects on innovation performance. According to the input-output economic theory, enterprises need to invest a lot of resources to conduct technological acquisition transactions. This kind of resource input can enable lead acquirers to enhance their innovation output and performance after adequately absorbing the technological innovation resources of acquirees. After a technological acquisition, the lead acquirer is expected to expand its knowledge base, and the increase in knowledge can help the enterprise build up its ability to create new technologies with the existing technological knowledge, thereby promoting corporate innovation (Ahuja and Katila, 2001). The technological acquisition events of high-tech listed companies in China show that technological acquisition has a positive impact on the post-acquisition innovation performance of lead acquirers, while non-technological acquisition exerts a limited influence. Acquisition transactions within an industry and the bargaining power enhancement of enterprises intensify competition in the industry, thereby forcing enterprises to better innovate (Ren Shuming et al., 2017). Even hostile takeovers may boost innovative behavior amongst enterprises (Atanassov, 2013).

Technological acquisition may have two possible consequences for enterprises: weakening the R&D ability and efficiency of core technical staff, or hindering the original R&D process or management approach. If two enterprises under a technological acquisition transaction find they fall short of consistency in such respects as organizational form, target market, or technological knowledge, it is very likely the transaction will eventually produce negative results (Ahuja and Katila, 2001). If a lead acquirer operates a fairly active capital market, then its R&D productivity will plunge after an acquisition transaction (Seru, 2014). Some scholars believe there is no relevance between technological acquisition and corporate innovation as no significant relations exist between technological acquisition transactions and the R&D intensity and efficiency of the surveyed high-tech listed companies in the U.S. (Desyllas and Hughes, 2010). Technological acquisition has a more remarkable influence on innovation ability in the long term than in the short term. The impact of technological acquisition on innovation varies by different time spans and industries (Entezarkheir and Moshiri, 2016). These considerations lead to the following second hypothesis.

H2: Technological acquisition boosts the subsequent innovation performance of the lead acquirer.

2.2 Innovation efficiency and technological overlap - two factors affecting technological acquisition

Innovation efficiency is the ability of an enterprise to convert its R&D input into innovation output. Enterprises with higher pre-acquisition innovation efficiency can produce more innovation outputs with fewer R&D inputs, such as a greater number of patents or new selfdeveloped products. According to Sevilir and Tian (2012), if two enterprises in an acquisition transaction consider their R&D investment and innovation efficiency to be mutually relevant, then they can obtain incentives from higher innovation output, take steps to further ensure continued R&D input, and deliver better innovation performance, thus forming a virtuous circle.

High innovation efficiency of a lead acquirer is very likely to increase its appeal to an acquiree, raise the expectations of both parties for the upcoming M&A transaction, and motivate the acquiree to accept the M&A offer. On this basis, the M&A proposal is more likely to come to fruition. In addition to high innovation efficiency, impressive innovation ability possessed by a lead acquirer can better facilitate the integration of resources and technologies on the two sides following the M&A transaction - a prerequisite for the enhancement of post-M&A innovation performance. Bena and Li (2014) studied a U.S. patent-merger dataset and found that acquirers are companies with higher innovation efficiency (large patent portfolios and low R&D expenses). For a lead acquirer, higher innovation efficiency means greater innovation capacity. In a technological acquisition transaction, the lead acquirer could better judge the technological value of the acquiree and become more aware of the relevancy of both parties and differences in terms of technological knowledge. Thus, the lead acquirer can make more rational decisions on technological acquisition, including the selection of an acquisition target. Therefore, the following two hypotheses are made.

H3: For a lead acquirer, innovation efficiency produces a moderating effect on the innovation performance achieved by its independent R&D efforts.

H4: For a lead acquirer, innovation efficiency produces a moderating effect on its innovation performance after a technological acquisition.

The theory of technological acquisition facilitation holds that such acquisition plays a positive role from both technological and acquisitional perspectives. First, it fosters the reserve of technological knowledge and updates to technologies and technological complementarity of both the acquirer and acquiree, and second it instills innovation avoidance in the lead acquirer due to the use of repeated knowledge prior to an acquisition transaction. In this sense, the acquirer and acquiree are more successful in technological innovation by fully leveraging economies of scale that arise from their knowledge integration (Bena and Li, 2014). There is, however, a negative correlation between the post-M&A innovation performance of a lead acquirer and the technical knowledge base of an acquiree.

When an acquiree has strong technical similarity to a lead acquirer - that is, a considerable technological overlap exists between the two - both parties can realize efficient, integrated operations after an M&A event. This is because similar technologies and shared cognitive structures create favorable conditions for them to communicate and learn from each other. As the lead acquirer is familiar with the technological knowledge of the acquiree, it can use its existing knowledge base to accurately assess the possibility of applying the acquiree's patented technologies and identify any potential difficulty for converting such technologies into economic value. This process thus provides the criteria for the lead acquirer to select an appropriate acquiree before an acquisition transaction.

If the existing technologies of a lead acquirer are completely irrelevant to the technical base of an acquiree, then both enterprises may encounter problems in staffing and resource integration after the M&A transaction. Moreover, it is impossible for the lead acquirer to fully exploit its existing technological base or harness the post-M&A economies of scale. Under such circumstances, the enterprise may see its post-M&A innovation performance stagnate or decline for a certain period of time.

Vermeulen and Barkema (2001) proposed that technological acquisition can help a lead acquirer to update its existing knowledge due to the knowledge complementarity between the acquirer and acquiree. In this way, the lead acquirer can to some extent avoid the innovation inertia and simplicity caused by its repeated use of existing knowledge and improve the quality and performance of its after-acquisition technological innovation. Bena and Li (2014) believed the technological overlap between the acquirer and acquiree before an M&A transaction could somewhat moderate the role that the innovation input and innovation ability of the lead acquirer plays in the technological acquisition process. When there is technological overlap between the two parties, the lead acquirer can expect its innovation input intensity and innovation ability to be greater within its areas of expertise. In addition, the matching degree of technical knowledge on both parties will also have a significant impact on the post-M&A innovation performance of the lead acquirer. Therefore, the following hypothesis is presented.

H5: The technological overlap between the acquirer and acquiree produces a moderating effect on the innovation performance brought about by the independent R&D intensity.

Figure 1 shows the overall inspection structure of this research with our five hypotheses.

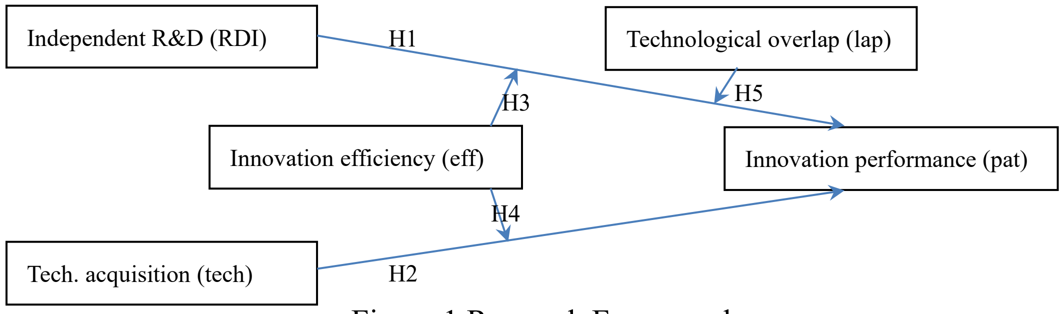

Figure 1 Research Framework

3. Sample and data

Considering the technologies accumulated by enterprises from their innovation activities, this study takes the number of patent applications filed by Chinese enterprises, including invention patents and utility models, as an indicator to measure their innovation performance. The three explained variables selected are the number of patent applications submitted by a lead acquirer in the year when an M&A transaction takes place, in the year after M&A, and in the two years after M&A. The data on the number of patent applications, the year of acquisition, and other aspects of content have a time span from 2011 to 2018. The data on the invention patents and utility models obtained by the surveyed Chinese enterprises are manually retrieved from the Dawei Innojoy patent database.

The summarized data of acquisition events used in this paper are sourced from the M&A sector of the Choice platform, and the selected acquisition events are those conducted and completed by non-Special Treatment listed companies on the main boards of Shanghai and Shenzhen over the five year period from 2012 to 2016. The acquisition samples are screened by pursuing the following principles: (1) Overseas M&As and those denominated in currencies other than RMB are all excluded; (2) If a lead acquirer triggers multiple M&A events within a year, only the one with the largest transaction amount is selected as a sample for the year; (3) To be selected as a sample, an acquisition event must meet the condition that the lead acquirer holds at least 50% of the acquiree after the acquisition event; (4) The duration of an acquisition event starts from the date of the first announcement; and (5) M&A events with incomplete data are excluded from samples. Corporate data such as total R&D expenditures come from annual financial statements of related enterprises, which can be retrieved from the CNRDS Database, CSMAR Database, and Choice Databases.

According to Ahuja and Katila (2001), a technological acquisition should meet either of the following two criteria: (1) an acquiree has obtained patents within five years before an acquisition transaction; (2) a lead acquirer explicitly mentions the transfer of technologies or technological resources of an acquiree in its M&A announcement. However, this paper finds it problematic to determine whether a transaction is a technological acquisition with the aforesaid second criterion, since large amounts of data are missing from the M&A announcements and prospectuses contained in the M&A databases. Therefore, this research selects the first criterion mentioned above to determine whether a sample is a technological acquisition. This paper then sets whether an acquiree has obtained patent rights within five years prior to the date of the first M&A announcement as an explanatory variable and then measures it like a dummy variable. If an M&A event is identified as a technological acquisition, then this variable is assigned the value of “1”; otherwise, it is assigned “0”.

Another explanatory variable is independent R&D intensity. Sevilir and Tian (2012) identified that the degree of importance and intensity of input to innovative R&D activities within an enterprise can be reflected through the ratio of the natural logarithm of its R&D expenditures to the natural logarithm of its total assets. In other words, the variable can indicate an enterprise’s attitude towards and level of dependence on innovation activities.

Corporate innovation efficiency is the ratio of patent applications divided by its total R&D expenditures in that year. This indicator reflects to what extent an enterprise can convert its R&D expenditures into patents.

Drawing on the quantitative approach pursued by Bena and Li (2014) in their study of technological overlap between enterprise pairs, this research sets group invention patents and utility models into several hierarchical levels according to the International Patent Classification (IPC) system. Under the IPC system, patents are divided into section (A-H) classes (each represented by a two-digit Arabic numeral), sub-classes (each represented by an upper English letter), groups (each represented by an Arabic numeral consisting 1-3 digits), and sub-groups (each represented by an Arabic numeral consisting 2-4 digits). As defined in this paper, a technological overlap exists where two enterprises under an M&A transaction possess patents that fall into the same sections and classes. In this case, the value of the variable is “1”; otherwise, it is “0”. Inspired by previous research, we select the following control variables: size, age, return on assets, nature, and leverage ratio of an enterprise. The aforesaid variables are set out in Table 1.

Table 1. Summary of Variables and Calculation Methods

Variables	Variable Definition	Calculation Method
Innovation Variables		
Pat0	Innovation performance in the year of M&A	Ln (number of patent applications filed in the year of the lead acquirer's M&A + 1)
Pat1	Innovation performance in the year after M&A	Ln (number of patent applications filed in the 1 year after the lead acquirer's M&A + 1)
Pat2	Innovation performance in the two years after M&A	Ln (number of patent applications filed in the 2 years after the lead acquirer's M&A + 1)
Pat3sum	Overall innovation performance after M&A	Ln (total number of patent applications filed in the 2 years after the lead acquirer's M&A + 1)
Independent Variables		
Tech	Technological acquisition	Assigned 1 for technological acquisition and 0 for non-technological acquisition
RDI	R&D intensity	R&D expenditures/total assets of the lead acquirer
RDln	R&D strength	Ln (R&D expenditures + 1)
Control Variables		
Eff	Innovation efficiency	Number of patent applications in the year before M&A/logarithm of R&D expenditures
Lap	Knowledge & technological overlap before M&A	Assigned 1 if the acquirer and acquiree had patents in the same category before M&A and 0 for none
Size	Enterprise size	Ln (an enterprise's total assets)
Age	Enterprise's age	Time span from enterprise establishment to the year of M&A
ROA	Return on assets	An enterprise's return on assets
Pro	Ownership nature	Assigned 0 for SOEs and 1 for private enterprises
Lev	Gearing ratio	Total liabilities/total assets of the lead acquirer
Chr	Market characteristics	1 for ShenZhen and 0 for ShangHai stock exchange

This paper selects samples from valid M&A events of A-share and non-Special Treatment companies listed on the main board of China's Shanghai Stock Exchange and Shenzhen Stock Exchange during 2012-2016. After screening, there is a total of 578 M&A data samples, including 250 samples of technological acquisition events and 328 of non-technological acquisition events. Table 2 shows the data correlation analysis and descriptive statistics.

Table 2. Correlation Analysis and Descriptive Statistics

Var	Mean	S. D.	Min	Max	Pat0	Tech	Lap	Size	Prop	Age	Lev	ROA	RDI
Pat0	1.62	1.78	0	8.49	1								
Tech	0.53	0.50	0	1.00	0.71*	1							
Lap	0.31	0.46	0	1.00	0.53*	0.62*	1						
Size	22.55	1.30	19.09	27.20	0.16*	-0.01	0.06*	1					
Prop	0.46	0.50	0	1.00	-0.02	0.01	0.01	-0.07*	1				
Age	18.02	5.15	5.00	49.00	-0.19*	-0.23*	-0.16*	0.05	-0.06	1			
Lev	49.16	19.94	5.23	130.35	-0.01	-0.09*	-0.06	0.48*	-0.06	0.07*	1		
ROA	5.97	5.65	-19.96	31.11	0.04	0.05	0.05	0.01	-0.06	-0.07*	-0.24*	1	

RDI	0.78	0.07	0.41	0.94	0.33*	0.35*	0.20*	-0.11*	0.02	-0.12*	-0.15*	0.12*	1
Eff	2.58	15.59	0	267.45	0.45*	0.15*	0.17*	0.11*	-0.01	0.05	-0.01	-0.03	0.10*

Note: Definitions for all variables are reported in Table 1. $*$, $**$, and $***$ indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

There is a relatively significantly positive correlation between the number of M&A patents and technological acquisition decisions as well as a significantly positive correlation between enterprise technological acquisition decisions and knowledge relevance of the acquirer and acquiree before M&A. This suggests that the overlap of patent categories between the acquirer and acquiree before M&A is an important influencing factor for the lead acquirer to conduct technological acquisition. We divide M&A events into technological acquisition and non-technological acquisition and examine the relationship between enterprise innovation output performance, which is typically the number of patent applications and technological acquisitions, an enterprise's R&D intensity and efficiency, as well as the degree of technological overlap between the acquirer and acquiree before M&A.

This paper mainly draws on the research of Ahuja and Katila (2001) and Sevilir and Tian et al. (2018) and uses multiple linear regression to examine the influence of technological acquisition on the innovation performance of the lead acquirers. The specific models are listed as follow.

Model 1 is structured to test Hypotheses H1 and H2, with the number of patent applications filed by an enterprise taken as the explanatory variable, and technological acquisition and the lead acquirer's independent R&D intensity taken as independent variables. The control variable represents the variables of Size, Prop, Age, Lev, ROA in Table1:

$$Pat_{i,t+1} = \alpha + \beta_1 \mathrm{Tech}_{i,t} + \beta_2 \mathrm{RDI}_{i,t} + \gamma \mathrm{Control}_{i,t} + \varepsilon_{i,t} \quad (1)$$

Hypotheses H3 and H4 are tested on the basis of Model 1. The product of innovation efficiency with independent R&D and that of innovation efficiency with technological acquisition are taken as the explanatory variables. This is Model 2:

$$Pat_{i,t+1} = \alpha + \beta_1 \mathrm{Tech}_{i,t} + \beta_2 \mathrm{RDI}_{i,t} + \gamma \mathrm{Control}_{i,t} + \beta_3 \mathrm{Eff}_{i,t} + \beta_4 \mathrm{RDI}_{i,t} * \mathrm{Eff}_{i,t} +$$

$$\beta_5 \text{Tech}_{i,t} * \text{Eff}_{i,t} + \varepsilon_{i,t} \quad (2)$$

Hypothesis H5 is verified by investigating the influence of both technological overlap between the acquirer and acquiree on an enterprise's independent R&D as well as innovation efficiency on innovation performance after technological acquisition. Thus, technological overlap (yes/no) is introduced as an independent variable to structure Model 3:

$$Pat_{i,t+1} = \alpha + \beta_1 \text{Tech}_{i,t} + \beta_2 \text{RDI}_{i,t} + \gamma \text{Control}_{i,t} + \beta_3 \text{Eff}_{i,t} + \beta_4 \text{Lap}_{i,t} + \beta_5 \text{RDI}_{i,t} * \text{Lap}_{i,t} + \varepsilon_{i,t} \quad (3)$$

Here, α denotes the vertical intercept; β_k and γ (k=1, 2, …, n) are regression parameters; and ε stands for regression error. Dependent variables are innovation performance and the number of patent applications (Pat) in each of the three years from the year of M&A to two years after M&A. Independent variables are whether or not the acquisition is considered as a technological acquisition (Tech), the enterprise's innovation input intensity (RDI) in the year of M&A, the enterprise's innovation efficiency (Eff) in the year before the M&A event, and technological overlap (Lap) of both parties before the M&A.

4. Influence of technological acquisition on innovation performance

4.1 Influence of technological acquisition and R&D on innovation performance

This paper has structured multiple linear regression models to control the effects of different factors, with the aim of examining the influence of technological acquisition decisions on the innovation performance of the lead acquirer. Model 1 regression is subject to multi-collinearity test (omitted). The results are shown in Table 3.

Table 3. Results of Technological Acquisition and Independent R&D on Innovation Performance

VAR.	Pat0	Pat1	Pat0	Pat1	Pat0	Pat1	Pat2
Tech			2.50***	2.52***	2.36***	2.39***	2.22***
			(23.98)	(24.01)	(21.58)	(21.67)	(18.71)
RDI	8.80***	8.66***			3.09***	2.88***	3.03***
	(8.75)	(8.52)			(3.90)	(3.61)	(3.53)
Size	0.34***	0.31***	0.26***	0.23***	0.27***	0.25***	0.29***
	(5.59)	(5.09)	(5.78)	(5.15)	(6.13)	(5.46)	(5.94)
Age	-0.06***	-0.05***	-0.01	-0.01	-0.01	-0.01	-0.01
	(-4.30)	(-4.00)	(-1.42)	(-1.02)	(-1.30)	(-0.90)	(-0.86)
ROA	-1.12	-0.62	-0.41	0.07	-0.74	-0.24	-0.05
	(-0.89)	(-0.49)	(-0.44)	(0.07)	(-0.79)	(-0.25)	(-0.05)
Prop	-0.10	-0.03	-0.11	-0.04	-0.11	-0.04	0.01
	(-0.75)	(-0.25)	(-1.09)	(-0.42)	(-1.07)	(-0.39)	(0.10)
Lev	-0.69*	-0.50	-0.38	-0.17	-0.31	-0.11	-0.27
	(-1.70)	(-1.21)	(-1.23)	(-0.56)	(-1.02)	(-0.35)	(-0.84)
Con.	-11.35***	-10.97***	-5.06***	-4.81***	-7.74***	-7.31***	-8.31***
	(-7.26)	(-6.94)	(-5.26)	(-4.97)	(-6.60)	(-6.18)	(-6.54)
Obs.	578	578	578	578	578	578	578
Adj.R^2	0.19	0.17	0.54	0.54	0.55	0.55	0.49

Notes: This table shows the effects of technological acquisition (tech) or independent R&D (RDI) on the innovation performance in the year (Pat0), after one year(Pat1), after 2 year(Pat2) of M&A, respectively. Definitions for other variables are reported in Table 1. This results are used the regression Model 1 to test the hypotheses H1 and H2. ∗, ∗∗, and ∗∗∗ indicate statistical significance at the 10%, 5%, and 1% levels, respectively. T-test is in parentheses.

When the lead acquirer's independent R&D intensity RDI is the sole explanatory variable, it has a significantly positive correlation with its innovation performance after M&A, which is then weakened in the year after M&A. However, both show a positive correlation. This indicates the effect is attributable to independent R&D only in the regression models in the year of M&A and the year after M&A. Except for the relatively low overall significance (R^2<0.2), the F-values of the equations are significant. Hypothesis H1 is supported.

When technological acquisition (Tech) takes place, it is significant at the 1% confidence level. When the influence of both independent R&D and technological acquisition is taken into consideration, a significantly positive correlation exists between an enterprise's technological acquisition and its innovation performance in the three years from the year of M&A to two years after M&A. Thus, Hypothesis H2 is true. Moreover, the overall significance is enhanced

(R^2>0.5). This indicates on the basis of independent R&D that M&A of external innovative technological resources has a positive influence on innovation. Therefore, the overall significance is strengthened. An enterprise's size also significantly and positively correlates with its innovation performance three years after M&A at the 1% confidence level. Other control variables such as leverage, return on assets, and ownership nature all fail in the significance test.

Prior to M&A most of the enterprises had engaged in independent R&D, but their intensity of R&D differed. The M&A inevitably influences the original independent R&D and innovation system. Therefore, it is also necessary to consider the different influences and roles of independent R&D variables in technological acquisition. The following analysis is divided into the moderating and mediating effects of R&D.

4.2 Moderating effect of innovation efficiency

Table 4 shows the overall regression results of Model 3. The innovation efficiency *Eff* of an enterprise in the year of M&A, as an explanatory variable other than technological acquisition and independent R&D intensity, shows a significantly positive correlation with the enterprise's innovation performance in the year of M&A, in the year after M&A, and in the two years after M&A at the 1% confidence level. This indicates that the higher an enterprise's innovation efficiency is before M&A, the higher is its innovation performance in the three years after technological acquisition, proving the validity of Hypotheses H1 and H2.

To measure the moderating effect, innovation efficiency is added in the multiplicative interaction Model 2 with technological acquisition and independent R&D intensity (RDI) as explanatory variables (see Table 4).

Table 4. Moderating Effect of Innovation Efficiency

VAR	Pat0	Pat1	Pat2	Pat0	Pat1	Pat2	Pat0	Pat1	Pat2
Tech	2.16***	2.20***	2.04***	2.33***	2.28***	2.10***	2.31***	2.26***	2.09***
	(22.32)	(22.28)	(18.77)	(24.64)	(22.78)	(19.02)	(24.27)	(22.45)	(18.77)
RDI	2.84***	2.56***	2.58***	2.15***	2.15***	2.33***	2.50***	2.43***	2.48***
	(4.00)	(3.53)	(3.24)	(3.22)	(3.04)	(2.99)	(3.67)	(3.36)	(3.11)
Eff	0.24***	0.19**	0.12	2.22***	0.90***	0.69*	2.39***	1.03***	0.77**
	(2.81)	(2.21)	(1.29)	(7.31)	(2.79)	(1.96)	(7.67)	(3.12)	(2.10)
RDI*Eff	**-0.24****	**-0.18***	**-0.10**				**-0.22****	**-0.18***	**-0.10**
	(-2.36)	**(-1.78)**	**(-0.90)**				**(-2.28)**	**(-1.72)**	**(-0.86)**
Tech*Eff				**-2.18*****	**-0.86*****	**-0.66***	**-2.16*****	**-0.85*****	**-0.65***
				(-7.19)	**(-2.68)**	**(-1.85)**	**(-7.15)**	**(-2.64)**	**(-1.83)**
Size	0.20***	0.18***	0.22***	0.18***	0.16***	0.21***	0.19***	0.17***	0.21***
	(5.16)	(4.36)	(4.84)	(4.64)	(4.02)	(4.65)	(4.88)	(4.19)	(4.72)
Age	-0.02***	-0.02**	-0.02*	-0.02*	-0.02*	-0.02*	-0.02*	-0.02*	-0.02*
	(-2.59)	(-2.08)	(-1.91)	(-1.81)	(-1.75)	(-1.68)	(-1.80)	(-1.75)	(-1.68)
ROA	-0.10	0.41	0.63	0.01	0.49	0.67	-0.09	0.41	0.63
	(-0.12)	(0.49)	(0.68)	(0.01)	(0.59)	(0.74)	(-0.11)	(0.50)	(0.69)
Prop	-0.09	-0.02	0.03	-0.04	-0.01	0.04	-0.04	-0.00	0.04
	(-0.99)	(-0.23)	(0.29)	(-0.53)	(-0.07)	(0.41)	(-0.47)	(-0.02)	(0.43)
Lev	-0.05	0.15	-0.00	0.02	0.20	0.02	-0.02	0.16	0.00
	(-0.19)	(0.57)	(-0.01)	(0.08)	(0.73)	(0.08)	(-0.09)	(0.61)	(0.02)
Con.	-5.98***	-5.49***	-6.35***	-5.13***	-4.97***	-6.03***	-5.59***	-5.34***	-6.23***
	(-5.66)	(-5.09)	(-5.35)	(-5.14)	(-4.71)	(-5.19)	(-5.51)	(-4.97)	(-5.25)
Obs.	578	578	578	578	578	578	578	578	578
Adj.R^2	0.66	0.65	0.58	0.69	0.65	0.58	0.69	0.65	0.58

Notes: This table focus on the moderating effect of Innovation Efficiency (eff) and its interaction of the independent variables, such as, technological acquisition (tech) and independent R&D (RDI). The dependent variables are innovation performance in the year (Pat0), after one year(Pat1), after 2 year(Pat2) of M&A, respectively. Definitions of the other variables are provided in Table 1. This table shows the results of the regression Model 2 in order to test the hypotheses H3 and H4. ∗, ∗∗, and ∗∗∗ indicate statistical significance at the 10%, 5%, and 1% levels, respectively. t-test is in parentheses.

The table 4 shows that innovation efficiency can serve as a short-term moderator for independent R&D with statistical significance in only the first two years of M&A transactions.

In contrast, innovation efficiency can have a long-term, but decreasingly moderating effect on technological acquisition. A comparison between Table 3 and Table 4 indicates an increase in overall significance (R^2>0.6) and again shows that the addition of innovation efficiency helps better interpret the model. Hypotheses H3 and H4 are also verified. In other words, innovation efficiency has a significantly negative moderating effect on both variables.

We also analyze how innovation efficiency mediates independent R&D and technological acquisition. The mediation part is omitted here as the overall mediating effect is not significant. Economically, the innovation efficiency of acquirers should have a more practical effect of moderation than mediation, which has also been verified by these empirical results.

Contrary to many other studies, innovation efficiency has a negative interaction coefficient, which indicates a negative moderating effect of innovation efficiency. When acquirers improve their innovation efficiency, they also reach the level of innovation performance brought by independent R&D and technological acquisition. This is different from existing research (Sevilir and Tian, 2018). Lead acquirers with greater innovation efficiency can more effectively coordinate their technological resources, thus offsetting some innovation results from independent R&D, while technological acquisition allows faster integration of technological resources and creates synergy. In this light, innovation efficiency is crucial to corporate technological innovation. Higher innovation efficiency will create a siphon effect on R&D and M&A and reduce their overall influence on innovation performance. This also validates Hypotheses H3 and H4.

4.3 How technological overlap moderates post-M&A innovation performance

To examine the effect that technological overlap between the parties to M&A has on transactions on post-M&A innovation performance, we incorporate the presence of pre-merger technological overlap in Model 2 as an independent variable to create Model 3. When the role of innovation efficiency is included, the regression result is shown in Table 5.

Table 5. Technological Overlap Moderates Post-M&A Innovation Performance

VAR.	Pat0	Pat1	Pat2	Pat0	Pat1	Pat2	Pat0	Pat1	Pat2
Tech	2.13***	1.79***	1.46***	1.91***	1.66***	1.35***	1.93***	1.71***	1.38***
	(18.32)	(15.18)	(11.40)	(16.89)	(13.97)	(10.47)	(16.90)	(14.18)	(10.51)
RDI	1.96**	1.77**	2.22***	2.14***	2.43***	2.52***	1.65**	1.64**	2.08**
	(2.56)	(2.28)	(2.62)	(3.29)	(3.53)	(3.37)	(2.25)	(2.12)	(2.47)
Eff	2.44***	1.12***	0.84**	2.19***	0.98***	0.72**	2.23***	1.03***	0.75**
	(7.91)	(3.58)	(2.47)	(7.39)	(3.12)	(2.11)	(7.49)	(3.30)	(2.20)
Lap	-1.71	-1.92	-0.53	0.61***	1.02***	1.25***	-1.07	-1.65	-0.24
	(-1.40)	(-1.55)	(-0.39)	(5.25)	(8.34)	(9.45)	(-0.91)	(-1.34)	(-0.18)
Tech*Eff	-2.19***	-0.89***	-0.69**	-2.09***	-0.83***	-0.64*	-2.11***	-0.86***	-0.66**
	(-7.31)	(-2.94)	(-2.09)	(-7.29)	(-2.76)	(-1.95)	(-7.34)	(-2.84)	(-1.99)
RDI*Eff	-0.26***	-0.24**	-0.14	0.03	-0.08	-0.00	0.00	-0.12	-0.03
	(-2.66)	(-2.39)	(-1.33)	(0.32)	(-0.78)	(-0.03)	(0.05)	(-1.18)	(-0.24)
RDI*Lap	2.59*	3.53**	2.08				2.08	3.32**	1.86
	(1.71)	(2.30)	(1.24)				(1.43)	(2.17)	(1.11)
Lap*Eff				-0.09***	-0.04***	-0.04***	-0.09***	-0.04***	-0.04***
				(-7.21)	(-2.96)	(-2.81)	(-7.14)	(-2.86)	(-2.75)
Size	0.18***	0.14***	0.18***	0.15***	0.13***	0.16***	0.15***	0.13***	0.16***
	(4.67)	(3.74)	(4.19)	(4.14)	(3.37)	(3.89)	(4.21)	(3.50)	(3.95)
Age	-0.01*	-0.01	-0.01	-0.02**	-0.01*	-0.02	-0.02**	-0.01*	-0.02
	(-1.65)	(-1.47)	(-1.38)	(-2.38)	(-1.76)	(-1.64)	(-2.35)	(-1.72)	(-1.62)
ROA	-0.14	0.31	0.51	-0.09	0.34	0.54	-0.10	0.32	0.53
	(-0.18)	(0.39)	(0.60)	(-0.12)	(0.44)	(0.63)	(-0.14)	(0.41)	(0.62)
prop	-0.04	-0.01	0.04	-0.04	-0.01	0.04	-0.05	-0.01	0.04
	(-0.53)	(-0.11)	(0.39)	(-0.54)	(-0.07)	(0.41)	(-0.57)	(-0.12)	(0.39)
Lev	-0.01	0.22	0.11	-0.02	0.25	0.12	-0.05	0.21	0.10
	(-0.06)	(0.87)	(0.41)	(-0.09)	(1.00)	(0.45)	(-0.20)	(0.82)	(0.35)
Con.	-5.01***	-4.37***	-5.38***	-4.45***	-4.50***	-5.27***	-4.14***	-4.00***	-4.99***
	(-4.85)	(-4.17)	(-4.71)	(-4.57)	(-4.39)	(-4.73)	(-4.15)	(-3.81)	(-4.36)
Obs.	578	578	578	578	578	578	578	578	578
Adj.R^2	0.70	0.69	0.64	0.72	0.69	0.64	0.72	0.69	0.64

Notes: This table reports the results of the moderation of Technological Overlap (Lap) and its interaction of the independent R&D (RDI) and innovation efficiency (eff). Definitions of the other variables are provided in Table 1. This table shows the results of the regression model 3 to test the hypothesis H5. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. t-test is in the parentheses.

We see overall that R^2 in Table 5 is higher than that in Table 4 ($R^2>0.7$), which indicates that the addition of technological overlap helps to better interpret the model. The technological overlap of both acquisition parties passes the significance test. In particular, when technological overlap and innovation efficiency interact, technological overlap is found to have a more significantly positive effect.

There are also interactive short-term effects between technological overlap and independent R&D. High-overlap deals reflect proximity between parties in the knowledge base and technological resources. This means independent R&D can better promote technological synergy and realize the scale effect of technological resources. In such a light, positive interaction is found between both factors. Subsequently, innovation performance after acquisition events can be improved.

Technological overlap and innovation efficiency are negatively interactive. Technological overlap as a single factor has a significantly positive impact on innovation results. A higher degree of technological overlap reflects a smaller difference in resources from technological acquisition deals and the redundancy of know-how. The low difference of tech overlap diminishes technology efficiency and innovation performance. Technological overlap can sometimes serve as a substitute for innovation efficiency and independent R&D of acquirers. For this reason, technological diversification instead of technological overlap is more conducive to improving technological innovation.

Hypothesis H5 is empirically supported, suggesting an overall significant moderating effect of technological overlap. Nevertheless, a high degree of technological overlap contradicts and even substitutes for independent R&D and enhances the offsetting effect of efficiency after overlap. In summary, technological overlap is not conducive to innovation performance after technological acquisition.

4.4 The mediating or moderating effect of R&D from technological acquisition

As seen in Table 3, the conclusions converge when M&A performance in different years is included. For simplicity, we utilize a new explained variable, pat3sum, to reflect the overall innovation performance after M&A transactions. The regression analysis is shown in Table 6.

Before technological acquisition, lead acquirers usually have their own independent R&D system, which will be affected by M&A deals. Evidence provided in Szücs (2014), a U.S.-based study, and Haucap et al. (2019), based on EU firms, concluded that acquisition reduces R&D investment and intensity. We suppose that R&D has a certain mediating effect on technological acquisition and explore how technological acquisition affects innovation through R&D. The analysis is shown in Table 6.

Table 6. Mediating and Moderating Effect of R&D on Innovation

	(1)	(2)	(3)	(4)	(5)
Variables	Pat3sum	Pat3sum	Pat3sum	RDI	Pat3sum
Tech		**7.39*** **	**6.97*** **	**0.05*** **	**-0.08**
		(25.39)	**(22.90)**	**(8.46)**	**(-0.02)**
RDI	**25.86*** **		**9.01*** **		**5.36***
	(8.99)		**(4.08)**		**(1.89)**
Tech*RDI					**8.97*** *
					(2.03)
Size	0.99***	0.77***	0.81***	-0.00*	0.78***
	(5.77)	(6.13)	(6.50)	(-1.80)	(6.31)
Age	-0.16***	-0.04	-0.03	-0.00	-0.03
	(-4.26)	(-1.26)	(-1.13)	(-0.87)	(-1.09)
ROA	-2.15	-0.07	-1.02	0.11**	-1.14
	(-0.60)	(-0.03)	(-0.39)	(2.15)	(-0.44)
Prop	-0.12	-0.15	-0.14	-0.00	-0.14
	(-0.31)	(-0.52)	(-0.48)	(-0.23)	(-0.51)
Lev	-1.82	-0.89	-0.69	-0.02	-0.64
	(-1.57)	(-1.05)	(-0.82)	(-1.43)	(-0.77)
Constant	-34.01***	-15.55***	-23.36***	0.87***	-20.13***
	(-7.61)	(-5.80)	(-7.16)	(17.29)	(-5.55)
Observations	578	578	578	578	578
Adj.R^2	0.19	0.57	0.58	0.15	0.58
F	22.86	125.0	112.5	17.41	99.44

Notes: This table reports the results of different effect from R&D: the pre-M&A in column (1) , post- M&A in column (2) and (3) , mediating effect in column (1) and (4) which the path from tech through RDI to pat3sum, moderating effect in (5) , respectively . The results are the additional test on the hypotheses H1 and H2. ∗, ∗∗, and ∗∗∗ indicate statistical significance at the 10%, 5%, and 1% levels, respectively. t-test is in the parentheses.

Table 6 shows that the effect coefficient between original RDI and innovation before technological acquisition stands at 25.86 and is statistically significant below 1%. R^2 is 0.19. This means that Pat3sum is largely consistent with the results of the model shown in Table 3.

When M&A factors are considered separately, the coefficient between technological acquisition variables and innovation is 7.39 and R^2 is 0.57, with increasing significance overall. After technological acquisition (tech), the RDI coefficient declines from 25.86 to 9, and the tech coefficient is 7, both showing a significant effect on overall innovation performance. R^2 is 0.58, with a higher overall significance. Both M&A (tech) and R&D (RDI) have a significant effect (below 1%) on the overall innovation variable (Pat3sum). In other words, technological acquisition plays a role in the independent R&D system and overall innovation performance of acquirers. M&A factors such as talent, technology, patent, and other resources partially affect the independent R&D system of acquirers and contribute to new innovation effects. It is thus necessary to investigate the relationship between the two, because independent R&D arrives earlier than technological acquisition, and it is more practical to use R&D as a mediating variable.

A regression analysis on the mediating effect of RDI is used to analyze the effect of technological acquisition on innovation under the mediation of R&D, whereby RDI is a dependent variable and technological acquisition is an independent variable. As seen in Table 6, technological acquisition is significantly relevant to RDI, and RDI is also significantly relevant to innovation performance. The path coefficient (tech->RDI->pat3sum) is calculated as 0.05*25.86=1.29. The results demonstrate the relatively small effect of technological acquisition on innovation under the mediation of R&D when compared to the tech coefficient of 6.97 and the RDI coefficient of 9.01.

To analyze the moderating effect of technological acquisition on independent R&D, we add the multiplicative interaction term tech*RDI. It can be seen that the role of technological acquisition (tech) is no longer significant and that of independent R&D (RDI) declines markedly. The multiplicative interaction coefficient is significant below 5%. This means technological acquisition has a significant and full moderating effect on innovation.

4.5 Technological acquisition and innovation evolution under the composite moderating effect of innovation efficiency

Once the moderating effect of technological acquisition on independent innovation is verified in Tables 4 and 5, the hypothesis of RDI's mediating effect is examined and unproven. The moderating effect of efficiency and knowledge overlap is taken into account. To examine the evolution effect of innovation, the number of patents over the years is set as the dependent variable. The results of composite regression are shown in Table 7.

Table 7. Technological Acquisition and Innovation under the Composite Moderating Effect

Variables	Pat0	Pat1	Pat2	Pat3sum
Tech	-0.73	-0.63	0.31	-1.05
	(-0.68)	(-0.54)	(0.25)	(-0.34)
RDI	1.05	1.05	1.63	3.73
	(1.23)	(1.16)	(1.63)	(1.55)
Tech*RDI	**3.87*** **	**3.67** **	**2.25**	9.80**
	(2.81)	**(2.51)**	**(1.39)**	(2.53)
Eff	**2.50*** **	**1.13*** **	**0.83** **	4.46***
	(8.01)	**(3.43)**	**(2.26)**	(5.08)
Tech*Eff	**-2.21*** **	**-0.89*** **	**-0.68***	-3.78***
	(-7.35)	**(-2.79)**	**(-1.91)**	(-4.46)
RDI*Eff	**-0.29*** **	**-0.25** **	**-0.14**	-0.68**
	(-2.95)	(-2.33)	(-1.19)	(-2.42)
Size	0.18***	0.16***	0.21***	0.55***
	(4.74)	(4.05)	(4.63)	(5.14)
Prop	-0.04	-0.00	0.04	-0.00
	(-0.48)	(-0.03)	(0.42)	(-0.00)
Age	-0.01*	-0.01*	-0.02	-0.05*
	(-1.72)	(-1.67)	(-1.63)	(-1.92)
Lev	-0.02	0.17	0.01	0.15
	(-0.08)	(0.62)	(0.02)	(0.22)
ROA	-0.18	0.33	0.58	0.73
	(-0.23)	(0.40)	(0.63)	(0.33)
Constant	-4.36***	-4.17***	-5.51***	-14.05***
	(-3.97)	(-3.58)	(-4.27)	(-4.54)
Observations	578	578	578	578
Adj.R^2	0.69	0.66	0.59	0.71
F	116.4	98.44	72.92	123.3

Notes: This table reports the evolutional results(from Pat0 to Pat2 which means the patent number in the 0,1,2 year after M&A) of moderating effect from innovation efficiency(Eff). The results are the additional test on the hypotheses H3 and H4. ∗, ∗∗, and ∗∗∗ indicate statistical significance at the 10%, 5%, and 1% levels, respectively. t-test is in the parentheses.

As the table shows, the moderating effect of technological acquisition on independent R&D gradually reduces over time, and the overall post-M&A innovation performance declines. When the moderating effect of innovation efficiency is taken into account, there is a gradual end to the dilution effect of the multiplicative interaction term tech*eff on the overall post-M&A innovation performance.

One can conclude that technological acquisition and independent R&D affect innovation evolution. Moreover, the effect of technological acquisition on overall innovation decreases in the year of M&A, in the following year, and in the second following year. Concurrently, the siphonic effect of innovation efficiency diminishes. The result of the effect is verified through the effect on overall innovation.

4.6 Technological acquisition and innovation under the composite moderating effect of innovation overlap

Table 7 above focuses largely on the innovative features of acquirers, such as independent R&D and innovation efficiency. When the features of both M&A parties are considered, the effect of technological overlap is included. The results are shown in Table 8.

Table 8. Technological Acquisition and Innovation under the Composite Moderating Effect of Technological Overlap

Variables	Pat3sum	Pat3sum	Pat3sum	Pat2	Pat2	Pat2
tech	-1.05	-4.70	-3.67	0.31	-1.32	-1.08
	(-0.34)	(-1.13)	(-0.89)	(0.25)	(-0.77)	(-0.63)
RDI	3.73	3.56	3.33	1.63	1.56*	1.50
	(1.55)	(1.56)	(1.49)	(1.63)	(1.66)	(1.61)
Tech*RDI	**9.80****	**12.62****	**10.89****	2.25	3.49	3.08
	(2.53)	**(2.42)**	**(2.12)**	(1.39)	(1.63)	(1.44)
eff	**4.46*****	**4.61*****	**4.20*****	**0.83****	**0.90*****	**0.80****
	(5.08)	**(5.54)**	**(5.11)**	**(2.26)**	**(2.63)**	**(2.34)**
Tech*eff	**-3.78*****	**-3.87*****	**-3.71*****	**-0.68***	**-0.72****	**-0.68****
	(-4.46)	**(-4.81)**	**(-4.69)**	**(-1.91)**	**(-2.17)**	**(-2.06)**

RDI*eff	**-0.68****	**-0.76*****	-0.27	-0.14	-0.18	-0.06
	(-2.42)	**(-2.86)**	(-0.95)	(-1.19)	(-1.62)	(-0.53)
Lap		3.81	3.88		1.68	1.69
		(0.82)	(0.85)		(0.88)	(0.89)
RDI*lap		-1.62	-1.20		-0.64	-0.54
		(-0.28)	(-0.21)		(-0.27)	(-0.23)
Lap*eff			**-0.17*****			**-0.04*****
			(-4.67)			**(-2.64)**
size	0.55***	0.46***	0.42***	0.21***	0.17***	0.16***
	(5.14)	(4.49)	(4.19)	(4.63)	(3.92)	(3.72)
age	-0.05*	-0.04*	-0.05**	-0.02	-0.01	-0.01
	(-1.92)	(-1.65)	(-2.10)	(-1.63)	(-1.32)	(-1.56)
ROA	0.73	0.45	0.54	0.58	0.45	0.47
	(0.33)	(0.21)	(0.26)	(0.63)	(0.52)	(0.55)
prop	-0.00	-0.01	-0.01	0.04	0.04	0.04
	(-0.00)	(-0.03)	(-0.05)	(0.42)	(0.42)	(0.41)
lev	0.15	0.48	0.39	0.01	0.16	0.14
	(0.22)	(0.71)	(0.59)	(0.02)	(0.56)	(0.49)
Constant	-14.05***	-12.26***	-11.03***	-5.51***	-4.69***	-4.40***
	(-4.54)	(-4.15)	(-3.78)	(-4.27)	(-3.85)	(-3.62)
Observations	578	578	578	578	578	578
Adj.R^2	0.71	0.74	0.75	0.59	0.64	0.64
F	123.3	120.9	118.0	72.92	76.87	72.63

Notes: This table reports the results of moderating effect from innovation efficiency (Eff) and moderating effect from technological overlap (Lap). The results are the further test on the hypotheses H5. ∗, ∗∗, and ∗∗∗ indicate statistical significance at the 10%, 5%, and 1% levels, respectively. t-test is in the parentheses.

As Table 8 demonstrates, when the technological overlap is added, the moderating effect of independent R&D and technological acquisition on innovation performance remains clearly positive.

Innovation efficiency has a particularly positive effect on innovation in all regressions. When technological acquisition is added, tech*eff decreases innovation performance. This means that technological acquisition brings for external technological resources, which impact and weaken the innovation results of acquirers under the existing innovation efficient structures.

The interaction effect of technological overlap on independent R&D is insignificant, which disagrees with existing research. Lap*eff, the interaction term of technological overlap and innovation efficiency, has a negative effect. It suggests that technological overlap negatively impacts the existing innovation efficiency. Instead of technological diversification, technological overlap harms innovation performance when it interacts with innovation efficiency.

A further test is conducted to verify the moderating effect of technological overlap. The results appear in Table 9.

Table 9. Technological Acquisition and Innovation under the Composite Moderating Effect of Technological Overlap

Variables	Pat0	Pat1	Pat2	Pat0	Pat1	Pat2
Tech	-0.73	-0.63	0.31	-0.74	-1.50	-0.80
	(-0.68)	(-0.54)	(0.25)	(-0.71)	(-1.37)	(-0.67)
RDI	1.05	1.05	1.63	0.90	0.93	1.50
	(1.23)	(1.16)	(1.63)	(1.10)	(1.09)	(1.61)
Tech*RDI	3.87***	3.67**	2.25	3.36**	4.02***	2.74*
	(2.81)	(2.51)	(1.39)	(2.55)	(2.90)	(1.81)
Eff	2.50***	1.13***	0.83**	2.30***	1.10***	0.80**
	(8.01)	(3.43)	(2.26)	(7.70)	(3.50)	(2.34)
Tech*Eff	-2.21***	-0.89***	-0.68*	-2.14***	-0.89***	-0.68**
	(-7.35)	(-2.79)	(-1.91)	(-7.47)	(-2.95)	(-2.06)
RDI*Eff	-0.29***	-0.25**	-0.14	-0.04	-0.17	-0.06
	(-2.95)	(-2.33)	(-1.19)	(-0.39)	(-1.56)	(-0.52)
Lap				0.62***	1.03***	1.26***
				(5.36)	(8.49)	(9.52)
Lap*eff				-0.09***	-0.04***	-0.04***
				(-7.00)	(-2.72)	(-2.65)
size	0.18***	0.16***	0.21***	0.15***	0.12***	0.16***
	(4.74)	(4.05)	(4.63)	(4.00)	(3.22)	(3.79)
prop	-0.04	-0.00	0.04	-0.04	-0.01	0.04
	(-0.48)	(-0.03)	(0.42)	(-0.55)	(-0.07)	(0.41)
age	-0.01*	-0.01*	-0.02	-0.02**	-0.01	-0.01
	(-1.72)	(-1.67)	(-1.63)	(-2.28)	(-1.64)	(-1.57)
lev	-0.02	0.17	0.01	-0.01	0.26	0.13
	(-0.08)	(0.62)	(0.02)	(-0.06)	(1.04)	(0.47)
ROA	-0.18	0.33	0.58	-0.17	0.25	0.47
	(-0.23)	(0.40)	(0.63)	(-0.23)	(0.32)	(0.55)
Constant	-4.36***	-4.17***	-5.51***	-3.41***	-3.25***	-4.42***
	(-3.97)	(-3.58)	(-4.27)	(-3.24)	(-2.94)	(-3.66)
Observations	578	578	578	578	578	578
Adj.R^2	0.69	0.66	0.59	0.72	0.70	0.64
F	116.4	98.44	72.92	113.7	99.18	78.35

Notes: This table reports the evolutional results(from Pat0 to Pat2 which means the patent number in the 0,1,2 year after M&A) of moderating effect from innovation efficiency(Eff) and moderating effect from technological overlap (Lap). The results are the further test the hypotheses H3, H4 and H5. ∗, ∗∗, and ∗∗∗ indicate statistical significance at the 10%, 5%, and 1% levels, respectively. t-test is in the parentheses.

Table 9 indicates that the interactive motivation effect of technological acquisition and independent R&D on innovation performance decreases over time, with R^2 gradually diminishing from 0.7 to 0.5. Innovation efficiency remains significant, but also gradually decreases over time. In normalized regression, innovation efficiency remains significant. The siphonic effect of innovation efficiency on independent R&D and technological acquisition exhibits a downward curve. There is also a reduction in the effects of the interaction terms tech*eff and RDI*eff on the innovation revolution.

The technological overlap additionally replaces independent R&D and weakens the effects when independent R&D and efficiency interact. When the effect on innovation evolution is evaluated, the basic conclusions remain consistent without significant changes.

4.7 Robustness test

(1) Variable adjustment.

Cr5 represents the shareholding ratios of the top five shareholders of the enterprises and is an explanatory variable. It has a varying impact, direct or indirect, on the innovation behaviors and activities of enterprises. After another multiple linear regression with the new explanatory variable, the conclusion remains the same as the model examination results above. The results of explained variables Pat0 and Pat1 are listed in Table 10.

Table 10. Technological Acquisition and Innovation Examination under the Composite Moderating Effect

Variables	Pat0	Pat1	Pat0	Pat1	Pat0	Pat1
tech	-1.29	-1.30	-1.85	-1.53	-0.73	-0.63
	(-0.86)	(-0.83)	(-1.19)	(-0.97)	(-0.68)	(-0.54)
RDI	0.89	0.93	1.02	0.99	1.05	1.05
	(1.10)	(1.09)	(1.20)	(1.15)	(1.23)	(1.16)
Tech*RDI	**4.04****	**3.77***	**4.97****	**4.15****	**3.87*****	**3.67****
	(2.17)	**(1.92)**	**(2.57)**	**(2.11)**	**(2.81)**	**(2.51)**
eff	**2.30*****	**1.10*****	**2.52*****	**1.19*****	**2.50*****	**1.13*****
	(7.71)	**(3.50)**	**(8.16)**	**(3.79)**	**(8.01)**	**(3.43)**

Tech*eff	**-2.14*** **	**-0.89*** **	**-2.23*** **	**-0.92*** **	**-2.21*** **	**-0.89*** **
	(-7.47)	**(-2.94)**	**(-7.47)**	**(-3.05)**	**(-7.35)**	**(-2.79)**
RDI*eff	-0.04	-0.17	-0.31***	-0.28***	-0.29***	-0.25**
	(-0.39)	(-1.55)	(-3.11)	(-2.75)	(-2.95)	(-2.33)
Lap	1.47	0.71	1.43	0.70		
	(0.89)	(0.41)	(0.83)	(0.40)		
RDI*Lap	-1.06	0.39	-1.28	0.30		
	(-0.52)	(0.18)	(-0.60)	(0.14)		
Lap*eff	**-0.09*** **	**-0.04*** **				
	(-6.99)	**(-2.72)**				
size	0.14***	0.12***	0.16***	0.13***	0.18***	0.16***
	(3.90)	(3.21)	(4.28)	(3.42)	(4.74)	(4.05)
age	-0.02**	-0.01	-0.01	-0.01	-0.01*	-0.01*
	(-2.27)	(-1.65)	(-1.57)	(-1.40)	(-1.72)	(-1.67)
ROA	-0.18	0.25	-0.23	0.23	-0.18	0.33
	(-0.24)	(0.32)	(-0.30)	(0.29)	(-0.23)	(0.40)
prop	-0.04	-0.01	-0.04	-0.01	-0.04	-0.00
	(-0.53)	(-0.08)	(-0.48)	(-0.07)	(-0.48)	(-0.03)
lev	0.00	0.26	0.05	0.27	-0.02	0.17
	(0.01)	(1.01)	(0.19)	(1.07)	(-0.08)	(0.62)
Cr5	0.01	0.31	0.14	0.20	0.12	0.26
	(0.02)	(1.11)	(0.21)	(1.14)	(0.28)	(0.33)
Constant	-3.36***	-3.27***	-4.03***	-3.55***	-4.36***	-4.17***
	(-3.18)	(-2.94)	(-3.67)	(-3.18)	(-3.97)	(-3.58)
Observations	578	578	578	578	578	578
Adj.R^2	0.72	0.70	0.70	0.69	0.69	0.66
F	105.4	91.94	101.2	97.34	116.4	98.44

Notes: This table reports robustness checks on the main results using alternatives variables. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. t-test is in the parentheses.

The general results are roughly the same. Technological efficiency has a siphonic effect, and the interaction between technological overlap and efficiency is detrimental to innovation. This demonstrates that innovation is fostered by technological diversification rather than technological overlap.

(2) Grouped regression.

The samples are now classified as state-owned enterprises (SOEs) (prop=0) and private enterprises (prop=1). The new results are in Table 11.

Table 11. Differences between SOEs and Private Enterprises

Variables	Prop=0 Pat3sum	Prop=1 Pat3sum	Prop=0 Pat1	Prop=1 Pat1
RDI	2.92	3.76	0.91	1.04
	(0.91)	(1.09)	(0.73)	(0.82)
tech	-3.06	2.41	-1.82	1.19
	(-0.75)	(0.53)	(-1.15)	(0.71)
Tech*RDI	12.19**	5.49	5.09**	1.40
	(2.36)	(0.96)	(2.55)	(0.66)
Tech*eff	-3.76***	-8.47**	-0.94***	-1.19
	(-4.48)	(-2.26)	(-2.91)	(-0.86)
RDI*eff	-1.22***	**3.74*** **	**-0.44*** **	**1.15** **
	(-4.18)	(3.08)	(-3.90)	(2.56)
eff	4.91***	5.47	1.36***	0.27
	(5.64)	(1.41)	(4.03)	(0.19)
size	0.33**	0.64***	0.06	0.22***
	(2.45)	(3.87)	(1.23)	(3.65)
age	-0.02	-0.08**	-0.01	-0.03*
	(-0.82)	(-2.11)	(-0.74)	(-1.93)
ROA	-2.04	1.80	-1.13	1.05
	(-0.65)	(0.60)	(-0.93)	(0.94)
lev	0.18	0.30	0.33	-0.03
	(0.19)	(0.30)	(0.89)	(-0.09)
Constant	-8.82**	-15.78***	-1.96	-5.29***
	(-2.22)	(-3.35)	(-1.27)	(-3.03)
Observations	315	263	315	263
Adj.R^2	0.74	0.71	0.68	0.67
F	86.26	60.89	64.70	51.10

Notes: This table reports robustness checks on the group sample of SOE (prop=0) and private enterprises (prop=1). *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. t-test is in the parentheses.

Technological acquisition is more likely seen in SOEs, which boast a scale effect. In reality, SOEs form conglomerates through M&As. Contrastingly, private enterprises for whom the attraction of technological acquisition is low instead focus on survival and development. The innovation performance of private enterprises is elevated by RDI*, which is the interaction term of R&D and efficiency.

(3) PSM method.

The PSM-DID methodology is adopted to analyze how technological acquisition affects innovation performance.

Table 12. PSM-DID Test

	OLS	OLS	PSM
Variables	Pat3sum	Pat3sum	Pat3sum
RDI	26.24***	9.11***	12.14***
	(9.14)	(4.14)	(7.58)
size	0.86***	0.76***	0.07
	(5.73)	(7.01)	(1.06)
prop	-0.09	-0.12	0.01
	(-0.23)	(-0.44)	(0.08)
age	-0.16***	-0.03	-0.09***
	(-4.28)	(-1.13)	(-4.72)
ROA	-0.54	-0.42	-0.27
	(-0.16)	(-0.17)	(-0.17)
tech		6.99***	
		(22.99)	
DID			7.47***
			(25.68)
ATT			7.08***
			(22.43)
Constant	-32.31***	-22.70***	0.57***
	(-7.44)	(-7.18)	(2.69)
Observations	578	578	578
R-squared	0.19	0.58	0.53
r2_a	0.183	0.575	0.533
F	26.87	131.2	659.5

Notes: This table reports robustness checks by the different methods of OLS and PSM-DID. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. t-test is in the parentheses.

The PSM-DID test results show that technological acquisition has a significant impact. The OLS model that evaluates R&D finds R^2 to be 0.19. When technological acquisition is included, R^2 sees an obvious increase. In the PSM regression, DID is significant at 7.47, and R^2 is 0.53, which shows a small reduction. It verifies that different research methods have little influence on the research conclusion.

(4) Data update and treatment effect.

The treatment effect is adopted and patent samples in year 2019 are updated to analyze the above conclusions again. The results are listed in Table 13. It is proved that technological acquisition, as a technological policy, has a significant effect and positively incentivizes innovation.

Table 13. Treatment Effect of Technological Acquisition after Analyzing Updated Samples

Variables	ATE	POmean	OME0	OME1
r1vs0.tech	-4.41			
	(-1.40)			
0.tech		11.81***		
		(3.63)		
size			-0.02	1.03***
			(-0.46)	(4.94)
prop			-0.05	-0.07
			(-0.54)	(-0.15)
age			-0.02	-0.09*
			(-1.50)	(-1.94)
RDI			1.46**	14.13***
			(2.14)	(2.96)
eff			3.84	0.75**
			(0.69)	(2.12)
RDI*eff			0.69	-0.77*
			(0.10)	(-1.87)
lev			0.30	0.21
			(1.06)	(0.16)
ROA			1.50*	-0.70
			(1.70)	(-0.18)
Constant			-0.27	-25.62***
			(-0.26)	(-4.26)
Observations	670	670	670	670

Notes: This table reports robustness checks by the Data update from patent in the year 2019. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. t-test is in the parentheses.

After adjusting variables, applying new research methods, grouping samples, and updating samples, there is no significant evidence to demonstrate that technological acquisition impacts innovation. The results of existing explanatory variables include innovation input and innovation efficiency. The multiplicative interaction term of technological acquisition and innovation input remains consistent, which proves that the results are reliable.

5. Conclusion and implications

Technological acquisition, as a means of exogenous innovation, provides an effective boost to the post-deal innovation performance of listed companies under the moderation of independent R&D. Unlike companies that do not seek technological acquisition, acquirers witness a much higher number of patent applications within three years after the M&A transaction. The benefits of technological acquisition include less time and input needed to acquire the latest technologies, lower R&D risks, and a faster response to market changes.

We show that the relation between independent R&D intensity and technological acquisition-induced innovation performance of acquirers is significantly positive. If a company considers technological acquisition as a means of obtaining target technological resources and promoting its technological innovation, then continual investment in R&D innovation is necessary. Indeed, technological acquisition allows acquirers to obtain their target technological resources more easily. However, they can only realize technological innovation when the resources are internalized and adapted to their development purposes. Therefore, lead acquirers need to maintain R&D input while integrating target technological resources to achieve an efficient M&A process.

We also present that the independent R&D intensity of acquirers in the year of transactions expands the effect of technological acquisition on innovation performance, but the influence is significant in the short term. Subsequently, companies must maintain continuous and intensive innovation input beyond the technological acquisition, which will enable acquired technological resources to provide sustainable business value and technological support in the long-term pursuit of innovation. In summary, continuous R&D input is a prerequisite for companies to improve their post-M&A innovation performance in the long run.

Corporate innovation efficiency also has significant moderating and siphon effects on technological acquisition-induced innovation performance, and such effects remain for some time. Innovation efficiency refers to a company's ability to convert technological resources or R&D input into commercial production technologies or models within a given unit of time. Acquirers efficient at in-house innovation can effectively leverage the acquired technological resources to develop their patents and pursue technological breakthroughs. The role of innovation efficiency is more evident in its siphon effect on independent R&D and technological acquisition.

As we can see that technological acquisition helps public companies improve their innovation performance, the following suggestions are provided.

Technological overlap and innovation efficiency interact adversely with innovation performance. Technology-intensive companies in particular could find technological acquisition essential to obtain the resources necessary for short-term rapid development and technological breakthroughs. It can also promote their innovation performance for a long period of time after the transaction. Instead of relying on technological acquisition, companies should focus on endogenous innovation factors during the M&A process; e.g., maintaining R&D input and improving innovation efficiency. In addition, companies should make sound judgments about their technological overlap with target companies and avoid the impact of information asymmetry.

National policies should be introduced to realize a smooth transition from the monopoly of market resources to innovation-oriented technological acquisition. The encouragement of M&A deals with a view to knowledge and technological innovation would be one such suggestion. Tax, fiscal, and financial support measures should be provided to promote the pursuit of technological acquisition and technological innovation. In this way, enterprises can reap more benefits from technological acquisition.

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