The LMEs R&D Volatility, Innovation Output and Business Performance in Chinese High-tech Industry

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Abstract. The purpose of this paper is to explore the relationships among the R&D volatility, technological innovation output and business performance for the large and medium-sized enterprises' (LMEs) in Chinese high-tech industry. In order to test the above relationships, this paper builds an individual random effects model by the LMEs' panel data for Chinese high-tech industry; and then, the paper makes a robustness test by establishing a fixed effects model and a random effects model with some substitute variables. This empirical study shows that: the LMEs' R&D volatility in Chinese high-tech industry has a directly negative impact on technological innovation output, and also has a similar statistica lly impact on economic performance. While the LMEs' technological innovation output in Chinese high-tech industry has a statistical significantly positive impact on the business performance. This study also shows that the LMEs' technological innovation output has a partial intermediation role in the relationship between the LMEs' R&D volatility and operating performance in Chinese high-tech industry.

Keywords: R&D Volatility; Technological innovation output; Business performance; High-tech Industries

1. INTRODUCTION

The activity of research and development(R&D) is the key to improve the technological innovation capabilities, and also is an important for gaining the firm's competitive advantage in China's high-tech industry. Each period of R&D activities (including fundamental research, applied research, product development and target market) needs to input a lot of time and R&D resources. While if there is an unexpected event (such as 2008 financial crisis) happened during the period of R&D activity, there will be inevitably result the volatility of R&D foundation. In fact, the enterprises' R&D investment in high-tech industry is look like the "blood" of R&D activities. And if there has a large volatility or "drying up" for R&D foundation, the activities of R&D may be delayed or even interrupted.

Therefore, the volatility of R&D investment has an impact on the enterprise technology innovation output and business activities. In recent years,there are many scholars begin to explore the relationships among the fluctuation of R&D, technological innovation and business performance (such as Gupta et al.,2006; Harryson et al.,2008; Swift,2013; Mudambi and Swift, 2014). They focus on three issues: Firstly, does the volatility of R&D investment significantly exist in the process of enterprises' technological innovation activities (take an example Gupta et al., 2006; Harryson et al., 2008).

Secondly, does the volatility of enterprise R&D invest -tment cause the changes in business performance (Kor and Mahoney, 2005; Swift, 2013). Finally, is there a significantly relationship between the LMEs R&D volatility and technical innovation output (Schuelke-Leech, 2014). While above studies doesn't explore the relation -nship among the LMEs' R&D volatility, technological innovation output, and business performance in Chinese high-tech industry. This paper explores the above relationships by establishing an individual random effe -cts model based on the LMEs' panel data in Chinese high-tech industry during the year 2001 to2012.

This paper is organized as follows: in the second part, proposing the theoretical hypothesis based on the existing research experience. The third part describes the methods, selected variables and the sources of LM Es' panel data in Chinese high-tech industry. The fou rth section tests the above three hypothesizes by diff erently panel data models and giving the empirical res ults. Finally, this paper presents the corresponding co nclusions and suggestions.

2. THE THEORIES AND HYPOTHESES

2.1 R&D Volatility and Technological Innovation Output

R&D Volatility(hereinafter abbreviated RDV) refer s to the wave of R&D investment over time, which i s on behalf of the relatively stable level for enterprises' R&D activities. There is closely relationship between the LMEs' RDV and technological innovation output; due to R&D volatility is produced in the process of technological innovation activities; On the one hand, existing studies show that about 50% of R&D funds are paid for the wages of R&D personnel (Dai and Cheng,2013). Therefore, the fluctuation of R&D investment is likely to cause the loss of R&D personnel. Then due to the lack of R&D personnel, the progress of R&D activities is directly blocked or interrupted, which is not conducive to enhance corporate technological innovation output (Mudambi and Swift,2011). On the other hand, according to the principle of technical path dependence, when the more stable R&D volatility ensures continuity of enterprise innovation, and then continuous technological innovation behavior will now generate opportunity costs (Suárez,2014), thereby increasing the possibility for company decided to impleme-nt the technological innovation projects, and indirectly improving the likelihood of innovation output. In view of the above analysis, we propose hypothesis H1.

Hypothesis H1: In a certain scale of enterprises' R&D investment, the more stability of R&D volatility, the more conducive to increase the output of technological innovation.

2.2 Technological Innovation Output and Business Performance

Technological innovation output have an impact on business performance mainly through the following channels: firstly, with the constant improvement of the intellectual property system, technological innovation output is able to generate the monopoly profits by intellectual property protection, then improve the business performance (Rosenberg,1990). Secondly, some LMEs' technological innovation output (particularly for the disruptive technological innovation output) can greatly improve production efficiency, reduce production cost, and increase the business performance. Many studies show that there is a superior economic benefit for innovative enterprises (Wakelin,2001; Wang Xigang,2016). Third, enterprises often develop new products to meet market demand and develop new markets, and then contributing to corporate profits. Take an example, due to Yunnan Baiyao Group Co., Ltd. develop the new product (mainly band-aid and toothpaste) through technological innovation, the company creates new markets, and make a rapidly improvement of operating performance. In view of the above analysis, we propose hyp o-thesis H2.

Hypothesis H2: The more enterprises' technology i nnovation output, the more excellent business performance.

2.3 R&D Volatility and Business Performance

There are mainly two channels for the impact of R&D volatility on business performance: on the one hand, when the fluctuate of R&D investment is caused by achieving the short-term business performance, the type of R&D volatility may have a negative impact on long-term business performance. For example, when the corporate real earnings are lower than the revenue analysis and forecast, or CEO nearing retirement, the managers usually reduce R&D investment in order to achieve short-term earnings target. Therefore, this decision maybe damages long-term business performance (Baber, 1991). On the other hand, in the above section 2.1 and 2.2 analyses, R&D volatility also has indirect impact on business performance by technological innovation output. When the less volatile of R&D investment, enterprises always make the R&D personnel to maintain stability, ensure the continuity of innovation activities, increase the technological innovation output, and finally improve the business performance. In view of the above analysis, we propose the hypothesis H3.

Hypothesis H3a: the more stability of R&D volatility, the more excellent business performance.

Hypothesis H3b: technology innovation output has a partial intermediation role in the relationship between the R&D volatility and business performance.

3. RESEARCH METODS AND DATA

3.1 Research Methods and Variables

In order to verify above three hypotheses, this paper proposed the econometric models based on Cobb -Douglas production function:

$$Pate_{it} = \alpha_0 + \alpha_1 \ln(RDV_{it}) + \alpha_2 \ln(RD_{it}) + \alpha_3 \ln(Empl_{it}) + \varepsilon_{it} \quad (1)$$

$$\mathrm{Re}ve_{it} = \beta_0 + \beta_1 \ln(RDV_{it}) + \beta_2 \ln(Pate_{it}) + \beta_3 \ln(RD_{it}) + \beta_4 \ln(Empl_{it}) + u_{it} \quad (2)$$

Therein the indicator Reveit and Pateit respectively refer to the i-th industry of large and medium-sized enterprises(LMEs) operating performance and technolo-gical innovation output in the t(t=2001, 2002, ... ,2012) year. And RDVit, RDit, Emplit respectively refer to the i-th industry of large and medium-sized enterprise s'(LMEs) R&D volatility, R&D expenditure and R&D personnel in the t(t = 2001,2002, ..., 2012)year. $\alpha_k (k=0,1,2,3)$ and $\beta_j (j=0,1,2,3,4)$ are the corresponding parameters; ε_{it} and u_{it} are the corresponding residuals.

Based on the method of Mudambi and Swift (2011), this paper uses the exponential regression analy-sis of time trend estimates the RDV. First, the R&D expenditure (RD) for R&D activities is performed by exponential regression analysis of time trends:

$$RD_{it} = \alpha_i \cdot e^{\mu_i t} + \eta_i \quad (3)$$

Therein i is the i-th industry; t is respectively refer to the year 2001,2009, ..., 2011 and 2012; η_i is the residuals. Then, calculate the original of R&D volatility for the high-tech industry enterprises' R&D e xpenditure:

$$rdv_{it} = S_{it} / \overline{RD}_i \cdot 100\% \quad (4)$$

Therein rdvit refers to the original of i-th categor y of high-tech industrial enterprises'R&D volatility in t year. Sit indicates the standard residuals for RD, is e q-ual to the i-th industry of LMEs'RD minus the time trend values of RD in the t year which is calculated by above equation (3). $\overline{RD}_i$ is the average of the i type of industrial enterprises' R&D investment. Due to the symbol of rdv by calculated above the equation (4) i s positive or negative, and whether the symbol of rdv is positive or negative, indicating that there is R&D volatility of high-tech industrial enterprises. Therefore this paper uses the RDV which is equal to the squa re of rdv, that is:

$$RDV_{it} = (rdv_{it})^2 \quad (5)$$

In addition, using the number of LMEs' patent applications (Pate) in high-tech industry as a proxy i ndex for innovation output. Using the main business i ncome of the enterprise in the medium-sized high-tech industrial (Reve) as the proxy variables for operating performance. The control variables include LMEs' research and development investment(RD), research and development staff (Empl).

3.2 Data Sources

According to China's Bureau of Statistics on high -tech industry classification, the high-tech industries include pharmaceutical manufacturing, aerospace & a-viation industry, electronics and communications equip-ment manufacturing, computer and office equipment manufacturing and medical equipment and instrument manufacturing industry. The data used by this paper is from China National Bureau of Statistics official web site: click on the "data query-annual data -technology" (website http://data.stats.gov.cn/easyquery.htm?cn=C01), the time span of the year 2002-2012. The above var-iables are collected according to the large and medium -sized industrial enterprises (hereafter referred to as LMEs) caliber.

R&D volatility of Chinese high-tech industry ente-rprises is calculated by the equations (3), (4) and (5), and the result shows in figure 1. As can be seen from figure 1, there is less volatile of R&D investment for China high-tech industry enterprises in the year 2001 -2007, while there is greater volatility of R&D invest-ment for high-tech industry after the year 2008, which is maybe caused by the 2008 financial crisis.

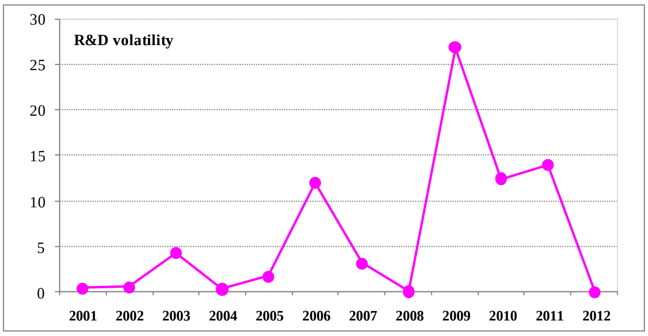

Figure.1 R&D volatility of Chinese high-tech industry enterprises (2001-2012)

4. EMPIRICAL RESULTS

4.1 Variables Stability Test

The results of variables stability test show in table 1. Wherein the variables of Pate, ln(RDV) and Reve are tested by the patterns of containing both the intercept and time trend, and other variables such as ln(RD) and ln(Empl) are tested by the intercept test mode. This test result shows that the five variables have passed at the 5% level of statistical significance, which indicates that the first-order sequence variables are stationary. Therefore, in the sequence step can directly make a regression analysis.

Table.1 The unit root tests for panel data

methods	the results of I(1)				
	Pate	ln(*RD*)	ln(*Empl*)	ln(*RDV*)	*Reve*
L.L.C. test	-7.229	-8.154	-6.700	-7.104	-8.255
B. t-test	-1.769	-	-	-3.153	-2.185
IPS test	-2.620	-5.898	-5.101	-1.986	-5.772
Fisher-ADF test	32.920	50.438	44.412	27.593	51.428
Fisher-PP test	21.506	53.811	49.190	57.406	66.322

4.2 Results of Empirical Analysis

This paper establishes an individual random effect model, according the results of Haussmann test. The result of individual random effects model is shown in table 2.

4.2.1 The Impact of R&D Volatility on Technological Innovation Output

Based on the basis model Ⅰ(A), this paper introduce the variable of R&D volatility to establish the model Ⅰ(B). The R2 significantly increased (from 0.571 increased to 0.658), as shown in table 2. The influence coefficient for the variable ln(RDV) is significant at the level of 5%. This result shows that there is significantly negative impact of the LMEs' R&D volatility on innovation output in Chinese high-tech industry.

This result is consistent with Mudambi and Swift (2014), and support the above hypothesis H1.Mudambi and Swift pointed out that enterprises need a stable and continuous R&D investment to ensure the continuity of R&D activities, which contribute to increase the number of technological innovation output. In fact, enterprise keeps the stability of the R&D investment in a long time will not only help improve the innovative spirit of scientists and R&D personnel(Mudambi and Swift, 2011), but also conducive to accumulate the innovation knowledge of enterprise, form the unique technology path dependence, thereby promoting technological innovation output.

Table 2 the results of empirical analysis

variables	dependent variables：Innovation output(Pate)				dependent variable：Business performance (Reve)					
	Model Ⅰ(A)		Model Ⅰ(B)		Model II(A)		Model II(B)		Model II (C)	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
ln(RDV)	-	-	**-0.099****	-2.002	**-0.081***	-1.819	-	-	**-0.069***	-1.840
ln(RD)	0.225	0.624	0.464	1.250	0.371	1.312	0.936*	1.935	0.727	1.438
ln(Empl)	1.183***	2.666	0.921**	2.003	0.970***	2.695	1.273***	3.666	1.137***	3.237
ln(Pate)	-	-	-	-	-	-	**0.817*****	2.763	**0.779****	2.573
Intercept	-1.601	-1.554	-2.051*	-1.979	-1.579*	-1.819	4.424**	2.033	3.812*	1.690
Adjusted R^2	0.571		0.658		0.529		0.733		0.746	

Note: "***", "**", "*" respectively represents a significant level of 1%, 5% and 10%.

4.2.2 The Impact of Technological Innovation Output on Business Performance

Comparing the model II(B) and the model II (C), the adjusted R2 significantly increased from 0.733 to 0.746; the coefficient of variable ln(Pate) are statistical significance separately at level of 1% and 5%. The result shows that there is significantly positive impact of the R&D volatility on business performance for the large and medium-sized enterprises in China's high-tech industry. Therefore this conclusion supports above the hypothesis H2. There is a similar study by Jie et al. (2014) and Li Wei (2015). Since the high-tech industry belong to the industry with the faster changes, any advantage caused by innovation is likely to quickly replace by a new product or a new form product. Therefore, the high-tech industry enterprises should continue to increase investment technological innovation activities, speed up the transformation for technological innovation, increase innovation output(Feng et al.,2012), even avoid new replacement or a new form(Nadkarni and Barr, 2008), in order to obtain the higher profits and even monopoly profits.

4.2.3 The Impact of R&D Volatility on Business Performance

On the one hand, observing the above model Ⅰ(B), model II(A) and model II(C), finding that the coefficient of variable ln(RDV) are separately statistical significance at the level of 5%,10% and 10%. That is R&D volatility has a statistically negative impact on the innovation output and business performance. Therefore, the conclusion supports above the hypothesis H3a. And on the other hand, observing the model II(B), model II(C), the coefficient of the variable ln(Pate) are both statistical significance at the level of 1%. That is innovation output has a statistically negative impact on business performance. Above all, the result shows that there is a significantly impact of R&D volatility on business performance, and the relationship between R&D volatility and operating performance is partially mediated by technology innovation output. Therefore, the conclusion supports above the hypothesis H3b. One of the reason maybe is that when the company CEO nearing retirement, corporate earnings did not reach the target profit or with a higher fluctuations of operating cash flow, enterprises often make a buffer by increasing the fluctuations of R&D investment to achieve short-term earnings targets (Minton and Schrand,1999), which is damaged the long-term profit of enterprise, and not conducive to achieve sustained business performance.

4.2.4 Robustness Test

In order to test the robustness of the above model Ⅰ and model II, the index new product sales(NR) of LMEs replace the variable of technological innovation output; The cost of new product development (PD) replaces R&D investment; the fluctuations of new product development (PDV) replace R&D volatility. Firstly, the result of unit root test for variables NR, PD and PDV shows that they are stationary series. And then according to the result of Hausman test, the model III and model IV are respectively established by the individual fixed effects model and the random ef-fects model, (shown in table 3). There are total 72 observations.

Table3 Stability test results

variables	dependent variables：New product sales(ln(*NR*))				dependent variable：Business performance (ln(*Reve*))					
	Model III(A)		Model III (B)		Model IV(A)		Model IV(B)		Model IV(C)	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
ln(*PDV*)	-	-	-0.024*	1.886	-0.081**	-2.319	-	-	-0.042***	-3.390
ln(*PD*)	0.692***	11.233	0.653***	10.218	1.408***	9.148	0.357***	3.717	0.190**	2.344
ln(*Empl*)	0.225**	2.481	0.243***	2.717	-0.474**	-2.547	0.022	0.243	-0.218***	-3.309
ln(*NR*)	-	-	-	-	-	-	0.566***	5.523	0.955***	20.113
Intercept	3.689***	21.315	3.755***	21.665	-6.080***	-14.216	-6.364***	-15.384	-7.890***	-45.397
Adjusted R^2	0.983		0.984		0.854		0.929		0.958	

Note: "***", "**", "*" respectively represents a significant level of 1%, 5% and 10%.

From the table3, it is not difficult to find that the LMEs' R&D volatility (PDV) has a statistically significant negative impact on the innovation output(NR) and operating performance(ln(Reve)) in the high-tech in dustry. Technological innovation output(NR) also has a statistically significant positive impact on business performance(ln(Reve)). That is the technological innovation output(NR) has incomplete mediating role in the relationship between R&D volatility and operating performance. The conclusion is consistent with above the statistical results in Table 2, which further holds the hypothesis H1, H2 and H3. Therefore, the conclusion of this study is certain stability. The conclusion is not changed by selecting different variables.

5. THE CONCLUSIONS AND SUGGESTIONS

5.1 The Conclusions

Take the LMEs in Chinese high-tech industry as an example, the paper explores the relationship among the LMEs' R&D volatility, technological innovation output and business performance. The data used by thi s paper is the panel data from the year 2002 to 2012. The result of this empirical analysis as following:

Firstly, the LMEs' R&D volatility in Chinese high-tech industry has a statistically significant negative impac t on technological innovation output and business performance. The greater volatility of LMEs' R&D i nvestment will be causing the lower technological innovation output and the more downturn business performance. If the company is able to maintain the l ong-term stability of the R&D investment, reduce or even avoid R&D fluctuation, it will make sure the ent erprises to continuously carry out R&D activities,which is not only conducive to accumulate the firm's innova tion knowledge, improve the productivity of technolo gical innovation output, but also help enterp-rises to ac hieve the higher business performance.

Secondly, above studies show that the LMEs' technological innovation output in Chinese high-tech industry has statistically significant positive impact on operating performance. Therefore, the LMEs in Chinese high-tech industry should continuously carry out technological innovation activities, increase innovation output, and further obtain the higher benefits or even monopoly profits.

The last but the most important is that this study also shows that the LMEs' technology innovation outp-ut in Chinese high-tech industry has incomplete mediating role in the relationship between R&D volatility an d operating performance. That is the negative impact of LMEs' R&D volatility on operating performance in Chinese high-tech industry is partly by enterprises' technological innovation output.

5.2 Suggestions

This paper proposes two policies and recommendations according to the above findings. On the one hand, in order to obtain sustainable competitive advantage and superior business performance, the LMEs in high-tech in Chinese industry should keep the stability of R&D investment by a variety of financing channels. Enterprises, especially locate in the eastern developed areas, are able to ensure the stability of R&D investtment by the collateral, guarantees or advantages of industrial clusters and other ways. On the other hand, the LMEs in Chinese high-tech industry should not only through its own carry out R&D activities or in the form of alliances actively involved in R&D activities, but also through the introduction, purchase or use of existing intellectual property and other ways to increase technological innovation output. Because it provides an important guarantee for enterprises to obtain business performance.

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