

Innovation Performance and Influencing Factors of Expansive Listed Companies

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ABSTRACT

The super efficiency DEA model and panel Tobit model were used in this study to conduct empirical research on innovation performance and its influencing factors in expansive companies based on patent and annual report data for A-shares, dilated listed companies in China from 2009 to 2015. Our results suggest that innovation performance in Chinese listed companies is generally stagnating at a low level, but scores for computer, communications equipment, electrical machinery, chemical, and pharmaceutical industries are high. There are significant differences in innovation performance between internal and external expansion companies. The internal expansion scale shows a significant negative correlation with innovation performance, while there is a "U" shaped nonlinear relationship between external expansion and innovation performance; the turning point appears when the external expansion scale is 0.2, that is, it is significantly negative to innovation performance below 0.2 (and vice versa). Firm age, firm size, executive pay, average age of executives, and depreciation have a negative impact on innovation performance, while equity concentration, capital intensity, and financial leverage have a positive impact on innovation performance.

Keywords: internal expansion, external expansion, innovation performance, super-efficiency DEA model, Panel Tobit model

INTRODUCTION

Modern China's economic structural contradictions are intertwined, downward pressure has increased, and economic development has entered a stage referred to as the "new normal". The engine of development has transformed from the traditional factor-driven to innovation-driven, and the government has begun to vigorously promote so-called "supply-side reform"; the primary goal of such reform is improving productivity through industrial restructuring. The demand for structural adjustments and upgrades must be met through innovation (Liu et al., 2015; Li and Zheng, 2016). To cope with downward pressure on the economy and the impact of technological innovation, more traditional enterprises have sought to enhance their capacity for innovation and to fit better into the transition process by increasing internal investment, mergers and acquisitions, or other forms of expansion in the capital market.

Domestic listed company investment has boomed in recent years. M&A activities have supported rapid expansion both at home and abroad, and the amount of M&A is increasing yearly (Table 1).

There are three main questions enterprises must answer in seeking to enhance their innovation ability. First, how does expansion itself impact innovation performance? Second, how does the expansion scale affect innovation performance? Third, what are the specific factors influencing innovation performance? These problems merit theoretical and empirical analysis, particularly for Chinese expansive companies as they attempt to secure innovation ability, transformation, and development in the supply-side reform context. There have been few studies to date on the innovation performance and influencing factors of Chinese expansive listed companies, however (Li and Chi, 2016; Zhu et al., 2016).

Contribution of this paper to the literature

- This paper uses the super-efficient DEA model to measure the innovation performance of enterprises, proposes that comparing two expansion methods from the perspective of innovative performance, and provides a reference for expansive enterprises.
- Instead of the discrete dummy variable, this paper chooses the continuous variable of the expansion scale, and further analyzes the mechanism of the internal and external expansion scale on the innovation performance.
- Considering the heterogeneity of enterprises, this paper studies the impact of enterprise characteristics on the innovation performance in the Shanghai and Shenzhen listed companies (including low-tech companies), and puts forward the adjustment objectives of the corporate governance structure.
- The blind expansion can actually hinder the company's innovation performance owing to the negative correlation between internal expansion and innovation performance.
- As the company expands externally (via mergers and acquisitions), the "U" shaped relationship between the scale of external expansion and innovation performance suggests that the scale of expansion should be restricted and that free cash flow should be kept to a minimum.
- In the early days of its establishment, the company should take advantage of financial leverage to build extensive financing, which mostly for investment in R&D innovation projects.

Table 1. The total amount of M&A in 2012-2016

Year	2012	2013	2014	2015	2016
Number of domestic M&A(Cases)	2667	2704	4180	4821	4804
Number of overseas M&A(Cases)	286	275	354	316	337
Sum of domestic M&A(billions)	83.6	138.2	225.6	422.1	329.7
Sum of overseas M&A(billions)	8.6	14.1	22.2	13.6	10.5

The goal of this study was to construct a super-efficiency DEA model for Chinese expansive listed companies, as well as to measure and compare the innovation performance of companies undergoing internal expansion and external expansion. The factors influencing innovation performance were determined, then their respective effects were explored via Tobit panel regression. The empirical results are then translated into workable solutions for improving innovation performance.

LITERATURE REVIEW

Since the study of Aghion et al. (1994), many scholars have explored the innovation performance of expanding enterprises. Expansion is a dynamic development process through which an enterprise grows from small to large as its competitiveness grows from weak to strong, and its management system and organizational structure grow from primary to advanced. Enterprise expansion can be internal or external; internal expansion mainly relates to self-investment, while external expansion occurs mainly in the form of corporate mergers and acquisitions (Karim and Mitchell, 2004; Jiang et al., 2009; Ye and Wang, 2013).

In recent years, the innovation performance and influencing factors of expansion in Chinese listed companies has been researched extensively. Jiang, for example, found that Chinese listed companies mainly engage in self-investment to expand; total investment and self-investment showed a significant positive correlation, but there was no significant relationship observed between total investment and M&A expansion (Ye and Wang, 2013; Jiang et al., 2008). Board activity, equity concentration, amount of free cash flow, and firm size are the main factors influencing expansion. Wen suggested that technology mergers and acquisitions can enhance innovation performance, but non-technology mergers and acquisitions has no such effect (Wen and Liu, 2011). Tang and Hu et al. found that listed companies in the Chinese pharmaceutical industry can improve their innovation performance by focusing on R&D investment or technology mergers and acquisitions, but that these approaches may not be optimal (Tang and Wu, 2014; Hu and Wu, 2015). Compared to large enterprises and state-owned enterprises, the synergistic effect mainly exists in small enterprises and private enterprises. Li et al. found that non-invention patent applications increase significantly as companies selected by industrial policies seek government subsidies and tax incentives; selective industrial policy encourages enterprises to make innovations so as to gain support from the government (Li and Zheng, 2016).

There is still controversy among researchers over the innovation performance and influencing factors of Chinese expansive listed companies. There is no consensus regarding measurements of innovation performance, for instance, among output, input, and multi-dimension aspects. Output-based performance measurement generally involves the number and quality of patents (Griliches, 1986; Acharya and Subramanian, 2007; Chava et al., 2013).

However, it is unrealistic to apply in China due to the lack of any patent citation database. Input-based measurement mainly uses the absolute indicators of R&D including technical staff, labor force, and fixed asset investment (Zhu et al., 2016; Hagedoorn and Cloudt, 2003; Mao et al., 2013; Tsai and Lei, 2016) and relative indicators like R&D investment intensity, which is generally adjusted with total assets or operating income (Liu et al., 2015; Deng et al., 2006; d’Artis et al., 2016). Multi-dimensional measurement is a more comprehensive description than single indicators of innovative performance, but is not particularly efficient (Hagedoorn and Cloudt, 2003; Romijn and Albaladejo, 2002; Chen and Liu, 2011). The precise impact of enterprise expansion on innovation performance is also somewhat controversial. Bena and Hu found that corporate external expansion is positively correlated with innovation performance (Hu and Wu, 2015; Bena and Li, 2014; Gunawan and Shieh, 2016), but others have found that the relationship between external expansion and innovation performance is more complex (Li and Zheng, 2016; Valentini, 2012; Seru, 2014).

There have been few studies on the impact of internal expansion on innovation activities. There have been a few studies on internal and external expansion to use discrete dummy variables to distinguish whether mergers or self-investment are appropriate, but these studies did not consider the impact of continuous expansion on innovation performance. Analyzing innovation performance and influencing factors under internal and external expansion is necessary to determine the related mechanisms in a systematic and comprehensive manner.

DATA AND INNOVATION PERFORMANCE

Data

In 2007, the CSRC made a formal request for the disclosure of R&D expenses of listed and proposed listed companies in accordance with the *Accounting Standards for Business Enterprises No. 6-Intangible Assets (Ministry of Finance)*. However, there are serious deficiencies in R&D expenditure data of listed companies in 2007 and 2008. With the listed companies in Shanghai and Shenzhen from 2009 to 2015 as samples, the following treatments were conducted in this study: (1) Similar to Yuan and Li, innovation investment was determined with a 1-year lag (Li and Zheng, 2016; Yuan et al., 2015). The lagged innovation input indicators match the current output indicators, and exclude samples with missing values. (2) ST or *ST samples were removed. (3) Extreme values were deleted by Winsorizing the top and bottom 1% of continuous variables.

We ultimately obtained 5,221 observations of 1,126 companies. The samples were divided into 617 non-expansive samples, 4,604 expansive samples (4,147 for internal investment and 457 for mergers and acquisitions). The research and development, patent, mergers and acquisitions data, and financial indicators discussed here were taken from the CCER database, the CSMAR database, and the Wind database.

Innovation Performance

Innovation performance measurement model

We used the super-efficiency DEA model to construct the innovation performance of the expansive listed companies (Li and Chi, 2016; Odeck and Brathen, 2012; Sueyoshi and Goto, 2013 Xiong et al., 2012). The super-efficiency DEA model is calculated as shown in Eqs. (1) and (2), where y_j^n and x_i^n are the input and output of the n th decision-making unit (DMU), and u_j^n and v_i^n are the calculated input and output weights. The final maximum value of θ_k^n is the DEA efficiency score of the n th decision unit.

$$Max\theta_k^n = \frac{\sum_{j=1}^J u_j^n y_j^n}{\sum_{i=1}^I v_i^n x_i^n} \quad s. t. \quad \frac{\sum_{j=1}^J u_j^n y_j^n}{\sum_{i=1}^I v_i^n x_i^n} \leq 1 \quad (1)$$

$$u_j^n, y_j^n \geq 0; \quad i = 1 \dots, I; \quad j = 1 \dots, J; \quad n = 1 \dots, N \quad (2)$$

Input indicators

Input indicators are generally defined as human capital investment and material capital investment. Most listed companies have two indicators of human capital investment: Numbers of personnel classified by education, and numbers of technical staff classified by their functional departments. Education data was generally lacking in our dataset, so we used a logarithm of the number of technical personnel as the human capital indicator. Because innovation and R&D activities are a process of knowledge accumulation and knowledge production, their output is related to both previous and current R&D expenditure. Similar to Cameron and Zhu, we take R&D capital stock

Table 2. Statistical descriptions of input and output indicators

Level 1	Level 2	Level 3	Abbreviation	Mean	SD	Minimum	Maximum
Input indicators	Labor	Technical personnel	TP	5.620	1.060	3.470	8.540
	Capital	Capital deposit of R&D	CDRD	17.06	2.510	8.880	21.22
Output indicators	Patent	Patent application	PA	2.560	1.150	0.690	5.740
	Others	ROE	ROE	8.150	8.180	-24.30	33.30

as a material capital investment indicator to measure innovation performance (Zhu et al., 2016; Cameron et al., 2005; Chen et al., 2017):

$$K_t = E_{t-1} + (1 - \delta)K_{t-1} \quad (3)$$

$$EPI = \alpha \times RMPI + (1 - \alpha) \times IFAPI \quad (4)$$

$$K_{2009} = E_{2009} / (g + \delta) \quad (5)$$

where K is R&D expenditure stock, E is the current R&D expenditure, depreciation rate δ is determined to be 15%, and α is 0.5. The expenditure price index is first constructed according to Eq. (4), then R&D expenditure is converted in different periods into a constant price. EPI, RMPI, and IFAPI respectively represent R&D expenditures, the price index of raw material purchases, and the fixed asset investment price index. Eq. (3) is then used to obtain the capital stock of R&D, and Eq. (5) to determine the capital stock in the base period. Here, we use 2009 as the reference year; g is the R&D expenditure arithmetic average growth rate for each sample. Finally, the R&D expenditure of the base year calculated from the first two steps and the R&D expenditure adjusted by the price index are substituted into Eq. (3), then the current capital stock value of R&D is obtained and its logarithm is taken as the input index.

Output indicators

Based on previous studies by Becker, Tong, and Li, we divided innovation output into patent output and other output (Li and Zheng, 2016; Becker-Blease, 2011; Tong et al., 2014). The number of patent applications can be used to measure innovative output, with the patent application year as the company's year of innovation production. Due to the uncertainties and instabilities in patent grants, which are subject to annual fees, we did not use the number of patent licenses (Tan et al., 2014); using solely patent output as an indicator is limiting, so we also selected the most widely used business performance measurement indicator (ROE) to ensure comprehensive analysis. As the patent data was right-skewed, the PA variables were 1% and 99% percentile Winsorized and added to 1 to obtain a natural logarithm.

Table 2 shows that the mean of technical personnel is 5.62, the mean of R&D capital stock is 17.06, and the corresponding standard deviation is relatively small; the mean of patent applications is 2.56, the standard deviation is 1.15, and ROE is 8.15 corresponding to a standard deviation of 8.18, which indicates that this index of data fluctuates within a wider range.

Measurement and Analysis of Innovation Performance of Listed Companies

Overview of listed companies' innovation performance

During 2009-2014, the average innovation performance of the whole sample was 0.667, which is far lower than that of the effective situation. (The efficiency score equals 1.) Figure 1 shows that the industries with the highest efficiency are leasing and service (L), followed by the farming industry (including agriculture, forestry, animal husbandry, and fishery) (A). The average efficiency of these industries for six years was 0.79 and 0.75, respectively. The lowest average innovation efficiency was within the wholesale and retail industry (F), with a score of only 0.51.

As shown in Figure 2, there was not much difference among the mean of innovation performance in six major industries, all of which decreased with time (Figure 2). Among them, innovation performance decreased more rapidly in 2010 than other years while decreasing more subtly in 2011-2014.

We selected another sample with innovation performance greater than or equal to 1 to further explore these results. There were 124 effective DMUs conforming to the condition, involving nine industries. The top seven effective DMUs were from the manufacturing sector, which contains 109 of the listed companies we examined comprising 87.9% of the total number of effective DMUs. In the manufacturing sector, the computer, communications, and other electronic equipment manufacturing industry has 16 listed companies performing efficiently. According to the National Bureau of Statistics directory, "high-tech industries" include computer, communications electronic equipment, electrical machinery manufacturing, chemical, and pharmaceutical

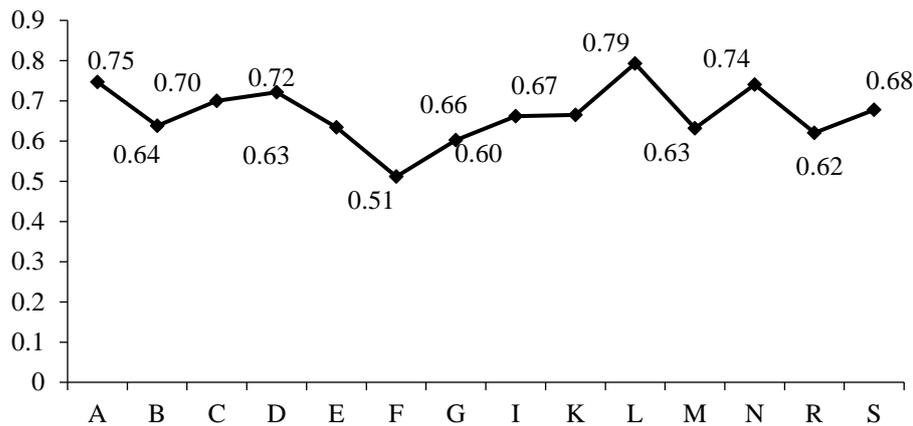


Figure 1. The mean of innovation performance in various industries in 2009-2014

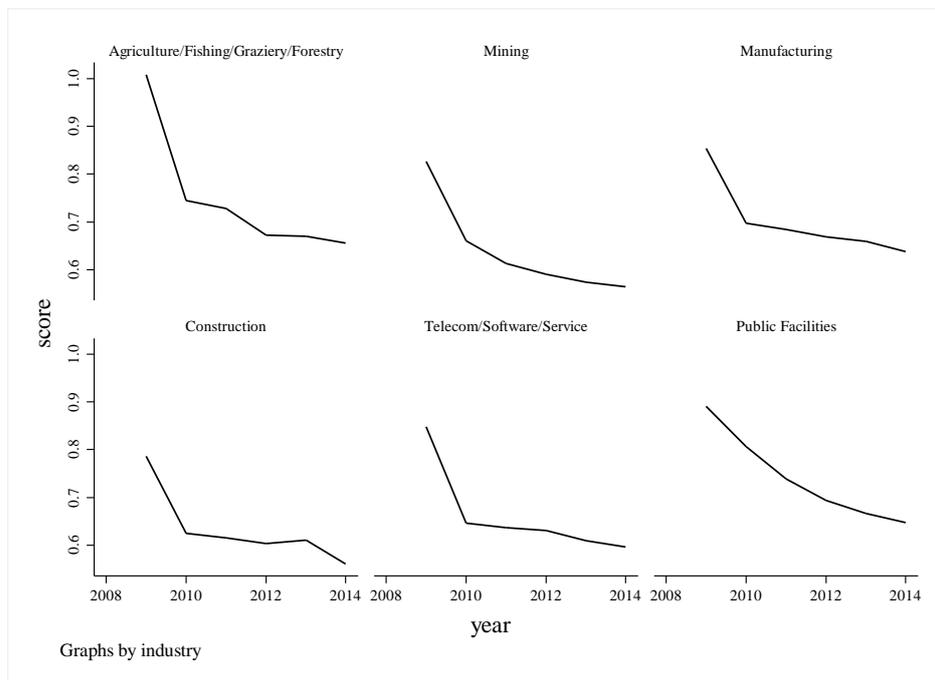


Figure 2. Innovation performance in six major industries in 2009-2014.

companies. It is reasonable to expect that these companies also have a high level of innovation performance efficiency.

Enterprise-level innovative performance in internal expansion and external expansion

We calculated the scale of internal expansion using the same method as Richardson and Jiang. The cash paid for the construction of fixed assets (the net cash recovered from the sale of fixed assets, intangible assets, etc.) was divided by the total assets at the beginning of the year; if the company’s internal expansion scale was greater than 0, it was classified as an internally expanding enterprise. External expansion was calculated as the total amount of M&A divided by the total assets at the beginning of the year; we deleted the samples from M&A with related companies or where M&A failed (Jiang et al., 2008; Richardson, 2006). If a year with the company saw several M&As, the amount of its M&A (the buyer’s payment) was summed as the external expansion of that year. When the company’s external expansion scale was greater than 0, it was classified as an externally expanding enterprise.

After classification per the above conditions, we obtained 4,147 observations of internal expansion and 457 observations of external expansion. As shown in Figure 3, the lines of internal expansion and external expansion in 2009-2014 were significantly different. In 2008-2011, the mean innovation performance of internal expansion was

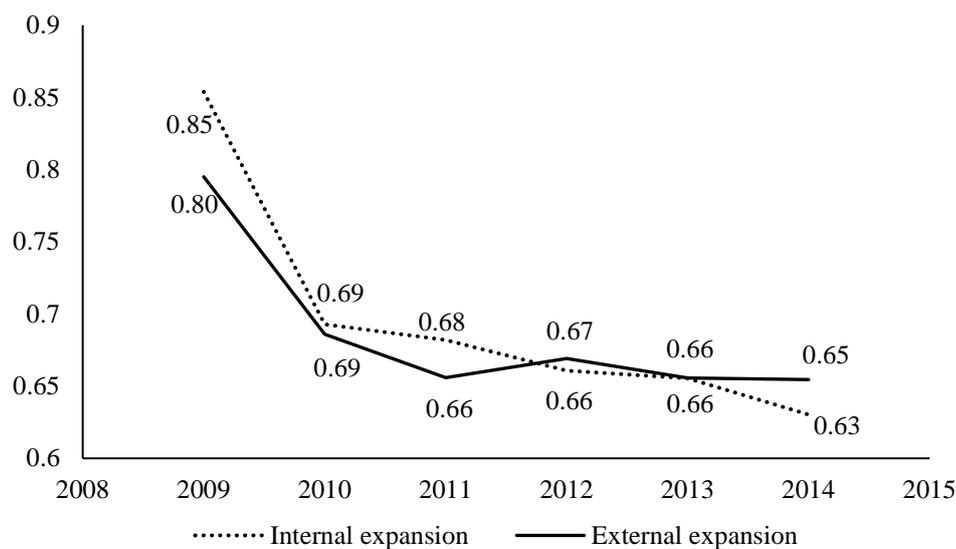


Figure 3. The average innovation performance of internal and external expansion companies in 2009-2014

Table 3. T-test of innovation performance of internal expansion and external expansion firms

Variables	Hypothesis	F-test	Sig.	T-test	Df.	Sig.(2-tailed)
TP	Equal variances assumed	11.992	0.001	1.213	4602	0.225
	Equal variances not assumed			1.335	591.39	0.182
CDRD	Equal variances assumed	53.74	0.000	-5.144	4602	0.000
	Equal variances not assumed			-7.307	729.86	0.000
PA	Equal variances assumed	0.048	0.827	2.925	4602	0.003
	Equal variances not assumed			3.001	568.6	0.003
ROE	Equal variances assumed	3.779	0.052	2.585	4602	0.010
	Equal variances not assumed			2.79	584.54	0.005
Score	Equal variances assumed	21.604	0.000	3.362	4602	0.001
	Equal variances not assumed			3.843	605.69	0.000

higher than that of external expansion, but after 2012, the opposite was true. The T-test results for innovation performance (Score) also differed significantly (Table 3).

EMPIRICAL STUDY

First of all, this paper makes descriptive analysis of each variable, and investigates the correlations between variables to avoid multicollinearity’s disturbance. Then, we use panel Tobit model to carry out empirical analysis, and explore the influencing mechanism of the expansion scale and other influencing factors on the innovation performance of the listed companies with different samples.

Variables

There are many factors that affect the innovation performance of listed companies, but have not formed a complete index system yet. Based on the previous literature and theory, this paper chooses a lot of factors such as firm size and age, equity balance, manager background, industry characteristics, organizational redundancy and cash flow. The concrete definitions of the relevant variables in this paper are shown in Table 4.

Methodology

Most of the innovative performance scores obtained from the super-efficient DEA model fell between 0 and 1. Only a small number reached the effective frontier of scores greater than 1, with a lower limit. Although the super-efficiency DEA model does not contain B_{it} , lower limit A_{it} still exists, so that the innovative performance scores obey censored distribution. If the traditional least squares regression model is used for regression analysis, the parameter estimation will be biased and inconsistent. The Tobit model following the maximum likelihood method

Table 4. Variables' definitions

Variables type	Variables name	Abbreviation	Description
Dependent variable	Innovation performance	Score	The efficiency score calculated by the super-efficiency DEA model
	Technical personnel	TP	Ln(The number of technical personnel)
Independent variables	Capital deposit of R&D	CDRD	Ln(The capital stock value of R&D) calculated by perpetual inventory method
	Patent application	PA	Ln(patent application + 1)
	Return on Equity	ROE	(Net profit after tax)/ equity
	Internal expansion scale	IES	(Cash paid for the construction of fixed assets-net cash recovered from the sale of fixed assets and intangible assets, etc.)/(total assets at the beginning of the year)
	External expansion scale	EES	(Total amount of M & A per year)/ (total assets at the beginning of the year)
	The square of external expansion scale	EES ²	The square of EES
	Control variables	Firm age	FA
Firm size		FS	Ln(total assets)
Ownership concentration		OC	The top 10 shareholders shareholding ratio
Board of Directors		SID	Size of independent directors
Executive salary		ES	Total remuneration of Directors, Supervisors and Senior Executives
Executive age		EA	Average age of directors, supervisors and senior management
Capital intensity		CI	Ln(Fixed assets/number of shareholders)
Cost income ratio		CIR	(Management fee)/(total operating income)
Free cash flow		FCF	(Net cash flow from operating activities-expected new investment)/(total assets at the end of last year)
Operating capacity		TAT	Total assets turnover=sales revenue /total Assets
Depreciation		DEP	Ln(depreciation and amortization in the current period)
Financial Leverage		FL	Asset-liability ratio=(total indebtedness)/(total assets)
Industry dummies		IND	According to the SFC (2010), divided into 12 industries

is a better choice for estimating the regression coefficient, so we selected it here. We also investigated panel fixation and random effects, as discussed below.

The Tobit regression dependent variable model is formulated as follows:

$$Y_{it}^* = \alpha_1 + \alpha_2 X_{it} + \varepsilon_{it} \tag{6}$$

$$Y_{it} = Y_{it}^*, Y_{it}^* > 0; \tag{7}$$

$$Y_{it} = 0, Y_{it}^* \leq 0 \tag{8}$$

Its more general form is:

$$Y_{it} = A_{it}, Y_{it}^* \leq A_{it} \tag{9}$$

$$Y_{it} = Y_{it}^*, A_{it} < Y_{it}^* \leq B_{it} \tag{10}$$

$$Y_{it} = B_{it}, Y_{it}^* \geq B_{it}; \tag{11}$$

where Y_{it} is the innovation performance score of listed companies, the lower limit A_{it} is 0, and B_{it} is 1 in the DEA model but does not exist in the super-efficiency DEA model, as there is no upper limit to innovation performance.

Firstly, (model-1) was constructed with the innovation performance score as the dependent variable and the internal expansion scale (IES), enterprise age (FA), enterprise size (FS), equity concentration (OC), independent board size (SID), executive salary (ES), executive age (EA), capital intensity (CI), cost income ratio (CIR), free cash flow (FCF), total asset turnover (TAT), depreciation (DEP), financial leverage, and industry as independent variables:

$$\begin{aligned} score_{it} = & \beta_0 + \beta_1 IES_{it-1} + \beta_2 FA_{it-1} + \beta_3 FS_{it-1} + \beta_4 OC_{it-1} + \beta_5 SID_{it-1} + \beta_6 ES_{it-1} \\ & + \beta_7 EA_{it-1} + \beta_8 CI_{it-1} + \beta_9 CIR_{it-1} + \beta_{10} FCF_{it-1} + \sum Control_{it-1} \\ & + \varepsilon_{it} \quad (model - 1) \end{aligned}$$

IES was replaced by EES as well as enterprise age, firm size, ownership concentration, the size of the independent board, executive pay, executive age, capital intensity, cost income ratio, free cash flow, total asset turnover, depreciation, financial leverage, and industry as independent variables to establish (model-2):

$$score_{it} = \beta_0 + \beta_1 EES_{it-1} + \beta_2 FA_{it-1} + \beta_3 FS_{it-1} + \beta_4 OC_{it-1} + \beta_5 SID_{it-1} + \beta_6 ES_{it-1} + \beta_7 EA_{it-1} + \beta_8 CI_{it-1} + \beta_9 CIR_{it-1} + \beta_{10} FCF_{it-1} + \sum Control_{it-1} + \varepsilon_{it} \quad (model - 2)$$

Finally, considering the inconsistency of the conclusions to the impact of the external expansion scale on innovation performance, we added the square of the external expansion scale to (model-3) to explore its non-linear relationship to innovation performance:

$$score_{it} = \beta_0 + \beta_1 EES_{it-1} + \beta_2 EES_{it-1}^2 + \beta_3 FA_{it-1} + \beta_4 FS_{it-1} + \beta_5 OC_{it-1} + \beta_6 SID_{it-1} + \beta_7 ES_{it-1} + \beta_8 EA_{it-1} + \beta_9 CI_{it-1} + \beta_{10} CIR_{it-1} + \beta_{11} FCF_{it-1} + \sum Control_{it-1} + \varepsilon_{it} \quad (model - 3)$$

All the independent variables were lagged 1 period. Among them, $score_{it}$ represents the innovation performance score; β_0 is the constant, $\beta_j (j = 1, 2, \dots, 12)$ for each variable regression coefficient, i is the order for firm $i (i = 1, 2, \dots, 1126)$, t represents the period $t = 1, 2, \dots, 6$, and ε_{it} is the residual.

Empirical Results

Descriptive statistics of variables

We deleted the missing samples among 4,604 expansion companies and reserved 4,240 observations for analysis, among which 3,783 were from internal expansion enterprises and 457 were from external expansion enterprises. The statistics for each sample are shown in Table 5 and Table 6.

Table 5 provides descriptive statistics of expansive enterprise variables. The mean of IES in the sample is 0.0795, and its median is 0.0533, indicating that more than half of the internal expansion of the enterprise has occurred below the 1% level; only a few enterprises have carried out large-scale internal expansion. The mean EES is 0.0187, and the minimum value is 0.000, corresponding to a sample with no external expansion; FA ranges from 1 year to 35 years with a mean of about 14.1 years. The mean of the firm size logarithm is 21.423; the size of the independent directors varies from 2 to 11 with the mean of 4.04 and a median of 3, indicating little difference in the values of these indicators. Most of the variables are around 3-5. EA ranges from 40 to 55 years old with only slight fluctuations.

Table 6 provides descriptive statistics of internal and external expansion enterprise variables. The mean innovation performance score of external expansion enterprises is 0.664, which is less than 0.685 of internal expansion enterprises. Due to the significant differences between the two types of samples, they were respectively regressed. For the other variables of both sample groups, the mean of the external expansion FA is 14.7 years is greater than 14.1 years of the internal expansion enterprises, with a corresponding minimum of 5 years.

Enterprises generally need to grow for some time to achieve external expansion. In enterprises undergoing external expansion, CIR appeared to be slightly higher than that of internal expansion enterprises. This is because enterprises need to integrate resources after M&A that expend more energy, resulting in increased management costs. The mean cash flow of the two sub-samples also differs: The internal expansion enterprise's FCF mean is -0.0443, indicating less available idle funds, while the mean FCF of the external expansion enterprise is 0.0951. These

Table 5. Descriptive statistics of expansion enterprise variables

Variables	Mean	Standard deviation	Median	Minimum	Maximum
Score	0.6837	0.1261	0.6674	0.4184	1.5342
IES	0.0795	0.0832	0.0533	-0.0412	0.4308
EES	0.0187	0.064	0.000	0.000	0.4266
FA	14.176	4.4876	14	1	35
FS	21.423	1.0672	21.282	19.273	24.887
OC	0.6284	0.1376	0.6485	0.2713	0.9106
SID	4.0462	1.788	3	2	11
ES	14.990	0.6663	14.950	13.431	16.841
EA	46.986	3.3589	47	40	55
FCF	-0.0305	0.5217	0.0408	-2.2175	2.3496
FL	0.3497	0.1954	0.3285	0.0325	0.8202
CIR	0.1022	0.0636	0.089	0.014	0.3826
CI	12.179	0.8975	12.2295	9.6543	14.355
TAT	0.7189	0.3869	0.6367	0.1527	2.3109
DEP	17.386	1.3183	17.309	14.512	21.272

Date source: CCER database, CSMAR database and Wind database

Table 6. Descriptive statistics of internal and external expansion enterprise variables

Variables	Internal expansion					External expansion				
	Mean	S D	Median	Min	Max	Mean	S D	Median	Min	Max
Score	0.6858	0.127	0.6688	0.4184	1.5342	0.6649	0.108	0.6470	0.4273	1
IES	0.0844	0.084	0.0573	0.0000	0.4308	0.0351	0.048	0.0222	-0.0412	0.2992
EES	0.0045	0.018	0.000	0.000	0.4266	0.1482	0.1405	0.0942	0.0002	0.4266
FA	14.114	4.522	14	1	35	14.741	4.121	14	5	31
FS	21.425	1.09	21.274	19.273	24.887	21.401	0.832	21.324	19.567	24.887
OC	0.6305	0.137	0.6513	0.2713	0.9106	0.6108	0.138	0.6357	0.2713	0.9106
SID	4.0223	1.759	3	2	11	4.2473	2.006	3	2	11
ES	14.992	0.672	14.952	13.431	16.841	14.973	0.611	14.938	13.431	16.841
EA	46.972	3.362	47	40	55	47.100	3.332	47	40	55
FCF	-0.0443	0.532	0.038	-2.217	2.3496	0.0951	0.389	0.0828	-1.790	2.3496
FL	0.3524	0.196	0.3329	0.032	0.8202	0.3250	0.187	0.3025	0.0325	0.8202
CIR	0.1001	0.061	0.0877	0.014	0.3826	0.1212	0.075	0.103	0.0164	0.3826
CI	12.172	0.901	12.2211	9.654	14.355	12.240	0.856	12.315	9.6543	14.355
TAT	0.732	0.391	0.6515	0.152	2.3109	0.5998	0.315	0.5401	0.1527	2.3109
DEP	17.392	1.341	17.311	14.512	21.272	17.327	1.089	17.281	14.512	21.272

scores suggest that the latter has more adequate capital. The variance and mean of the other indicators are nearly the same between the sample groups.

Multiple regression analysis

Table 7 shows the results of multiple regressions, where columns (1)-(3) are the results of panel Tobit regression. For comparison, we also carried out panel fixation effect and panel random effect regression. Column (4) is the panel fixation regression results; columns (5) - (6) are panel random effect results.

On the basis of (model-1), the regression coefficient of IES on innovation performance is significantly negative (-0.035), indicating that a larger internal expansion scale is less beneficial to the innovation performance of the enterprise. Many studies have found that Chinese listed companies have low efficiency in investing in fixed assets. These inefficiencies, to some extent, also inhibit the improvement of corporate innovation performance. The panel fixation effect results also show a negative coefficient of internal expansion scale (-0.0541), which suggests that the negative effect is relatively stable.

FA and FS had a negative impact on the internal expansion enterprise's innovative performance (-0.0066 and -0.041), which makes sense as newly established, smaller enterprises are often able to flexibly overcome organizational inertia, have more urgent desire to secure technological innovations, and can more readily obtain major technological breakthroughs. On the one hand, the regression coefficient of the top 10 shareholders' shareholding ratio (OC) is significantly positive (0.0747), indicating that the higher concentration of ownership does reduce the agency problem caused by the separation of powers, which will help improve the innovation efficiency of the company. In terms of executive background, the coefficients of executives' salaries and mean age are significantly negative (-0.0017 and -0.0284), indicating that high pay is more likely to lead to inertia in older executives while younger executives may be more willing to try innovative projects.

The coefficient CI is significantly positive (0.0272), which suggests that greater the capital intensity enhances innovation performance. The coefficient of CIR is significantly negative (-0.317), which means that enterprises with low management performance have limited creative ability. In the internal expansion sample, the impact of FCF on innovation performance is not significant; conversely, the coefficient is negative in the external expansion regression, indicating greater cash flow through these companies; more available idle funds mean more investment opportunities, but not necessarily more investment in innovation. We observed a negative correlation between free cash flow and innovation performance in the external expansion sample.

The asset-liability ratio is significantly positive across all three models. Numerous studies have found that companies use debt financing to improve their financial leverage and reduce conflicts of interest between managers and shareholders.

In (model-2), the regression coefficients EES are positive but not significant. There is no consensus regarding the impact of external expansion on the performance of corporate innovation, so we built (model-3) by adding the square of external expansion scale to test whether there is a nonlinear relationship between the external expansion EES and innovation performance (score). The (model-3) results show positive square coefficients of the external expansion scale (0.596), while the original non-significant primary is significantly negative (-0.246), indicating that there is a "U" shaped relationship between the external expansion scale and the innovation

Table 7. Results of multiple regressions

	(1)	(2)	(3)	(4)	(5)	(6)
	score	score	score	score	score	score
IES	-0.0351*			-0.0541**		
	(-1.77)			(-2.45)		
EES		0.0106	-0.246**		0.00888	-0.253**
		(0.41)	(-2.37)		(0.35)	(-2.44)
EES ²			0.596**			0.608***
			(2.55)			(2.60)
FA	-0.00660***	-0.000421	-0.000729	-0.0284***	-0.000513	-0.000821
	(-10.19)	(-0.38)	(-0.65)	(-15.99)	(-0.45)	(-0.72)
FS	-0.0410***	-0.0458***	-0.0442***	-0.0652***	-0.0470***	-0.0453***
	(-8.33)	(-4.61)	(-4.48)	(-7.91)	(-4.72)	(-4.56)
OC	0.0747***	0.0834**	0.0861***	-0.0175	0.0858**	0.0885***
	(4.30)	(2.49)	(2.59)	(-0.65)	(2.53)	(2.62)
SID	0.00063	-0.000243	-0.000285	0.00266***	-0.00000311	-0.0000553
	(0.75)	(-0.14)	(-0.17)	(3.03)	(-0.00)	(-0.03)
ES	-0.0284***	-0.0239***	-0.0228***	-0.0172***	-0.0240***	-0.0229***
	(-7.54)	(-2.86)	(-2.75)	(-3.32)	(-2.83)	(-2.71)
EA	-0.00170**	-0.00258*	-0.00258*	0.00200*	-0.00256*	-0.00256*
	(-2.34)	(-1.91)	(-1.92)	(1.90)	(-1.85)	(-1.86)
CI	0.0272***	0.0378***	0.0377***	0.0182***	0.0372***	0.0371***
	(9.51)	(6.58)	(6.61)	(4.86)	(6.45)	(6.48)
CIR	-0.317***	-0.267***	-0.266***	-0.120*	-0.268***	-0.267***
	(-7.53)	(-3.50)	(-3.52)	(-1.94)	(-3.45)	(-3.46)
FCF	-0.00226	-0.0202**	-0.0198**	-0.000162	-0.0205**	-0.0200**
	(-0.86)	(-2.09)	(-2.08)	(-0.06)	(-2.12)	(-2.09)
TAT	0.00107	-0.0216	-0.0214	-0.0318***	-0.0233	-0.0232
	(0.15)	(-1.18)	(-1.17)	(-2.99)	(-1.25)	(-1.26)
FL	0.0640***	0.0903***	0.0888***	0.0895***	0.0917***	0.0904***
	(4.39)	(2.87)	(2.84)	(4.49)	(2.88)	(2.85)
DEP	-0.0252***	-0.0139*	-0.0158**	-0.000539	-0.0129*	-0.0148**
	(-6.29)	(-1.87)	(-2.12)	(-0.08)	(-1.73)	(-1.99)
IND	Yes	Yes	Yes	Yes	Yes	Yes
_cons	2.230***	1.877***	1.876***	2.450***	1.894***	1.892***
	(28.46)	(11.72)	(11.79)	(15.76)	(11.72)	(11.77)
LR/R ²	3686.916	509.297	512.489	0.4018	0.3237	0.3615
N	3783	457	457	3783	457	457

Note: (1) *** Indicates statistical significance at the 0.01 level; ** Indicates statistical significance at the 0.05 level. * Indicates statistical significance at the 0.10 level; (2) Brackets for t-value or z-value;

performance of the listed companies. In other words, there is negative correlation when the external expansion occurs on a smaller scale. When the external expansion scale reaches 0.2063¹, there is a positive correlation.

As shown in Table 6, the mean and the median of the external expansion scale in the external expansion sample are 0.1482 and 0.0942, respectively, indicating that most of the enterprises we sampled did not reach the turning point. The effect of external expansion on the innovation performance of the listed companies is negative, which is consistent with the mean of innovation performance (0.665) of the internal expansion sample being lower than the that of the non-expanding sample (0.683) (Table 6).

We also found no difference between the coefficients, size, and significance of the other factors in the regression between the sample groups. Apart from the differences in FCF coefficients mentioned above, we also observed a significant negative correlation between FA and the innovation performance in the internal expansion sample, but not in the external expansion sample. Columns (5) and (6) also show where firm age has no significant effect on external expansion enterprise innovation performance.

¹ The quadratic function vertex coordinate formula is $-b / 2a = 0.246 / (2 * 0.596) = 0.2063$.

Table 8. Results of new groups

Variable	Expansion mode	Number	Mean	Standard deviation	Mean standard error
New score	Internal expansion	4147	0.6810	0.126168	0.001959
	External expansion	457	0.6615	0.107934	0.005049

Table 9. Results of independent sample T test

Variable	Hypothesis	F-test	Sig.	T-test	Df	Sig.(2-tailed)
New score	Equal variances assumed	20.121	0.000	3.168	4602	0.002
	Equal variances not assumed			3.588	602.16	0.000

Table 10. Results of robust test 1

	(1)	(2)	(3)	(4)	(5)	(6)
	New score	New score	New score	New score	New score	New score
IES	-0.0401***			-0.0630***		
EES		0.00754	-0.254**		0.00497	-0.263***
EES ²			0.608***			0.623***
FA	-0.00622***	-0.000349	-0.000664	-0.0283***	-0.000493	-0.000814
FS	-0.0411***	-0.0443***	-0.0426***	-0.0577***	-0.0460***	-0.0442***
OC	0.0730***	0.0772**	0.0799**	-0.0109	0.0805**	0.0832**
SID	0.000651	0.000209	0.000167	0.00271***	0.000566	0.000521
ES	-0.0291***	-0.0252***	-0.0241***	-0.0153***	-0.0255***	-0.0244***
EA	-0.00153**	-0.00244*	-0.00244*	0.00186*	-0.00240*	-0.00241*
CI	0.0288***	0.0389***	0.0388***	0.0190***	0.0379***	0.0378***
CIR	-0.324***	-0.267***	-0.266***	-0.104*	-0.268***	-0.267***
FCF	-0.00638**	-0.0204**	-0.0200**	-0.00375	-0.0208**	-0.0203**
TAT	-0.00784	-0.0286	-0.0286	-0.0400***	-0.0316*	-0.0318*
FL	0.0591***	0.0885***	0.0867***	0.0738***	0.0898***	0.0885***
DEP	-0.0256***	-0.0162**	-0.0181**	-0.00278	-0.0146**	-0.0166**
IND	Yes	Yes	Yes	Yes	Yes	Yes
_cons	2.222***	1.886***	1.885***	2.294***	1.910***	1.909***
LR/R ²	3806.4461	516.68931	520.12539	0.4028	0.3250	0.3639
N	3783	457	457	3783	457	457

Note: (1) *** Indicates statistical significance at the 0.01 level; ** Indicates statistical significance at the 0.05 level. * Indicates statistical significance at the 0.10 level; (2) Brackets for t-value or z-value;

Robustness Test of Panel Data Model

We performed a robustness test to determine the reliability of the regression results. We first replaced the output variables, then performed another regression analysis of the whole expansion sample.

Replacing output variables for regression analysis

The preceding output variables are the number of patent applications and ROE. Theoretically, the output of innovation should include patent output as well as other kinds of outputs, but there are many factors that can affect ROE. We deleted the ROE to verify the robustness of the results presented above, and only used the number of patent applications as output variables to re-calculate the innovation performance score by means of the super-efficiency DEA model. As reported in **Table 8** and **Table 9**, the results were basically the same; in effect, the mean and variance of the innovation performance of internal expansion and external expansion enterprises do significantly differ, and our sample classification is meaningful.

The robustness test results are provided in **Table 10**. Corresponding to **Table 7**, columns (1)-(3) are the results of the panel Tobit model; columns (4)-(6) are the panel fixation and panel random effect results. The IES coefficients in columns (1)-(3) are significantly negative (-0.0401); the square of external expansion scale (EES²) is 0.608 (0.596, **Table 7**), and EES is -0.254 (-0.246, **Table 7**), with a turning point of 0.2088 (0.2063, **Table 7**). Furthermore, the coefficients and symbols of other influencing factors are mostly consistent with the previous results, but with some notable differences. For example, the company age coefficient in the sample of the internal expansion was significantly negative, while in the in the sample of external expansion was not significant at all. Also, from (4)-(6), it can be inferred that panel fixation effect and the panel random effect are also consistent with the previous results.

Table 11. New variables' definitions

New variables	Abbreviations	Descriptions
IES dummy variable	d1	If classified to IES d1=1, otherwise d1=0
EES dummy variable	d2	If classified to EES d1=1, otherwise d1=0
Cross multiply term 1	d1IES	d1*IES
Cross multiply term 2	d2EES	d2*EES
Cross multiply term 3	d2EES ²	d2*EES ²

Extended whole sample regression analysis

As discussed above, we selected 3,783 internal extended samples and 457 external extended samples for analysis. We only used extended-listed companies in the sample data, so we were able to compare the internal expansion and external expansion samples while ignoring other factors in the non-expansion sample of listed companies. We next used a full sample of 4,827 observations to test the impact of expansion with (model-4), (model-5), and (model-6): We set dummy variables (d1: internal expansion, d2: external expansion) to indicate internal expansion versus external expansion, and added interactive items of the expansion scale specification (d1in, d2ex, and D2ex2) to explore the impact of the expansion specification on innovation performance. The description of the new variables is shown in **Table 11**.

$$score_{it} = \beta_0 + \beta_1 d1 + \beta_2 d2 + \beta_3 FA_{it-1} + \beta_4 FS_{it-1} + \beta_5 OC_{it-1} + \beta_6 SID_{it-1} + \beta_7 ES_{it-1} + \beta_8 EA_{it-1} + \beta_9 CI_{it-1} + \beta_{10} CIR_{it-1} + \beta_{11} FCF_{it-1} + \sum Control_{it-1} + \varepsilon_{it} \quad (model - 4)$$

$$score_{it} = \beta_0 + \beta_1 d1 + \beta_2 d2 + \beta_3 d1IES_{it-1} + \beta_4 d2EES_{it-1} + \beta_5 FA_{it-1} + \beta_6 FS_{it-1} + \beta_7 OC_{it-1} + \beta_8 SID_{it-1} + \beta_9 ES_{it-1} + \beta_{10} EA_{it-1} + \beta_{11} CI_{it-1} + \beta_{12} CIR_{it-1} + \beta_{13} FCF_{it-1} + \sum Control_{it-1} + \varepsilon_{it} \quad (model - 5)$$

$$score_{it} = \beta_0 + \beta_1 d1 + \beta_2 d2 + \beta_3 d1IES_{it-1} + \beta_4 d2EES_{it-1} + \beta_5 d2EES^2_{it-1} + \beta_6 FA_{it-1} + \beta_7 FS_{it-1} + \beta_8 OC_{it-1} + \beta_9 SID_{it-1} + \beta_{10} ES_{it-1} + \beta_{11} EA_{it-1} + \beta_{12} CI_{it-1} + \beta_{13} CIR_{it-1} + \beta_{14} FCF_{it-1} + \sum Control_{it-1} + \varepsilon_{it} \quad (model - 6)$$

Firstly, (model-4) uses two dummy variables as regression agent variables for regression, resulting in the first column of **Table 12**. The internal expansion (d1) and external expansion (d2) dummy variable coefficients are significantly negative (-0.0144 and -0.0173), indicating that neither expansion method is conducive to innovation performance in the whole sample. The coefficient of FA is also significantly negative.

To further explore the effect of expansion scale on innovation performance, we added the expansion scale interactive item to (model-4) to create (model-5). As shown in the second column in **Table 12**, the coefficient of internal expansion scale (d1IES) is significantly negative (-0.0392) and EES has no significant correlation with innovation performance. These conclusions are consistent with the results discussed above.

Next, in order to explore the nonlinear relationship between external expansion scale and innovation performance, the square of external expansion scale (d2EES²) was introduced to (model-5). In the third column of **Table 12**, the coefficient of d2EES² is significantly positive (0.644) and the coefficients of the linear term, though non-significant in (model-5), are significantly negative (i.e., are closer to our previous conclusions). The coefficient and size of the other factors are also similar to the previous conclusions.

Finally, for comparison, the regression results of the panel fixation model are reported in columns (4)-(6) of **Table 12**. Except for the coefficient of the sum of OC and FCF, which become non-significant, the coefficients of the other variables are basically consistent with that of the panel Tobit regression model.

In summary, the robustness test results did not significantly change the conclusions discussed in Section 4; the results presented here are reasonably stable.

Table 12. Results of robust test 2

	(1)	(2)	(3)	(4)	(5)	(6)
	score	score	score	score	score	score
d1	-0.0144***	-0.0122***	-0.0126***	-0.0152***	-0.0127***	-0.0132***
d2	-0.0173***	-0.0212***	-0.00775	-0.0103 [†]	-0.0171**	-0.00154
d1IES		-0.0392**	-0.0403**		-0.0520**	-0.0536***
d2EES		0.0233	-0.252**		0.0416	-0.280**
d2EES ²			0.644**			0.752***
FA	-0.00800***	-0.00809***	-0.00816***	-0.0283***	-0.0283***	-0.0285***
FS	-0.0527***	-0.0520***	-0.0520***	-0.0661***	-0.0635***	-0.0633***
OC	0.0734***	0.0757***	0.0760***	-0.0187	-0.0174	-0.0177
SID	0.000959	0.000965	0.000938	0.00287***	0.00286***	0.00283***
ES	-0.0310***	-0.0313***	-0.0311***	-0.0174***	-0.0174***	-0.0171***
EA	-0.00142**	-0.00148**	-0.00147**	0.00174**	0.00177**	0.00179**
CI	0.0246***	0.0245***	0.0245***	0.0190***	0.0185***	0.0185***
CIR	-0.270***	-0.274***	-0.273***	-0.104**	-0.0976 [†]	-0.0963 [†]
FCF	-0.00379	-0.00446 [†]	-0.00440 [†]	-0.000661	-0.00118	-0.00109
IND	Yes	Yes	Yes	Yes	Yes	Yes
_cons	2.408***	2.416***	2.415***	2.392***	2.402***	2.398***
LR/R ²	4767.8917	4770.4446	4773.6656	0.4009	0.4024	0.4039
N	4827	4827	4827	4827	4827	4827

Note: (1) *** Indicates statistical significance at the 0.01 level; ** Indicates statistical significance at the 0.05 level. [†] Indicates statistical significance at the 0.10 level; (2) Brackets for t-value or z-value;

CONCLUSION

This paper is based on China's A-share diluted patent data for listed companies from 2009 to 2015 and annual report data. By employing the super-efficiency DEA model and panel Tobit model, we conducted empirical research on innovation performance and its influencing factors for companies in different modes of expansion; our goal was to provide empirical evidence to support listed companies in the process of transformation and upgrading. Our findings can be summarized as follows.

The general innovation performance of Chinese listed companies is at a low level, but the computer, communications equipment, electrical machinery, chemical, and pharmaceutical industries exhibit quite high innovation performance. There are significant differences in innovation performance between internal and external expansion companies, as well. Internal expansion and innovation performance is significantly negative, while external expansion results in a "U" shaped relationship between scale and innovation performance with a turning point at scale of 0.2. In other words, when the external expansion scale is less than 0.2, innovation performance is negative; it is positive when the external expansion scale is greater than 0.2.

In our regression of factors affecting innovation performance, company age was significantly negative with innovation performance only in the internal expansion sample; it was not significant in the external expansion sample. When company is young, its innovation performance is more sensitive to the age of the company. Firm age has less impact on innovation performance as it increases. Free cash flow was not significant with innovation performance in the internal expansion sample, but was significantly negative in the external expansion sample. The company size, executive compensation, executive average age, and depreciation and innovation performance was significantly negative. Ownership concentration, capital intensity, and significant financial leverage coefficient were positive; independent director dimensions and total asset turnover appeared to exert no significant impact on innovation performance.

The results of this paper come with a few implications. First, that blind expansion can actually hinder the company's innovation performance owing to the negative correlation between internal expansion and innovation performance. As the company expands externally (via mergers and acquisitions), the "U" shaped relationship between the scale of external expansion and innovation performance suggests that the scale of expansion should be restricted and that free cash flow should be kept to a minimum. In the early days of its establishment, the company should take advantage of financial leverage to build extensive financing, which mostly for investment in R&D innovation projects.

We also found that independent directors did not play a significant role in improving innovation performance. New independent directors are typically paid higher salaries, as well; the company could instead use these funds to encourage younger, already entrenched executives to carry out more research and development activities.

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