The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/2515-8961.htm

How does research and development intensity influence the performance of firms through different stages in product life cycle?

Innovation & Management Review

Dan Li
Nanjing Xiaozhuang University, Nanjing, China

Received 5 April 2022
Revised 19 June 2022
20 July 2022
24 September 2022
9 September 2023
30 November 2023
Accepted 19 May 2024

Abstract

Purpose – It is widely acknowledged that the ability of a firm to develop and exploit their innovative capabilities is a critical determinant that maintains their competitive advantage. The purpose is to evaluate the research and development (R&D) inputs and outcomes on the performance of firms in different stages.

Design/methodology/approach – Drawing on a sample of 30 firms over 8 years (2009–2016), the results from a three-stage Bayesian stochastic frontier analysis model support were used.

Findings – Some interesting findings were discovered. First, the R&D intensity is positively associated with the number of patents granted, which is negatively associated with the number of new drug approvals (NDAs). Second, R&D inputs, including expenditures and human resources, are negatively related to the number of NDAs and firm performance. Third, state-owned firms perform better and have more patents granted than private-owned firms in China. Finally, the traditional Chinese medicine firms and non-coastal firms both gain fewer profits, but they generate more new drugs than chemical drug firms and coastal firms in terms of policy support.

Originality/value – It is revealed that there are no common factors among Chinese pharmaceutical firms except for ownership, and this heterogeneous behavior indicates that there is no common factor for enhancing the efficiency of all Chinese pharmaceutical firms.

Keywords Innovation, Bayesian stochastic frontier analysis, Performance, Efficiency

Paper type Research paper

Background

Research on evaluating firm performance has mainly focused on identifying the factors that contribute to the success of firms. Of these factors, innovative capability is widely recognized as a critical determinant that maintains competitive advantages (Bettis & Hitt, 1995; Grant, 1996). Some factors have been acknowledged as prerequisites to a firm's capability to

The author would like to thank the participants for their cooperation in the study.

Availability of data and materials: The dataset supporting the conclusions of this article are open and can be shared upon request. For further information on the data and materials used in this study, please contact the corresponding author.

Competing interests: The author declares no competing interests.

Funding: The work is supported by Jiangsu University Philosophy and Social Science Research Project (2021SJA0476). The funding agency played no part in either the design of the study or the collection, analysis, and interpretation of data, or in writing the manuscript.

Authors' contributions: The author confirms that the manuscript has been read and approved by him and that there are no other persons who satisfied the criteria for authorship but are not listed. The author further confirms that the order of authors listed in the manuscript has been approved by him. Author contributions are as follows: The author conceived/designed the study, analyzed data, drafted the manuscript and gave final approval of the submitted version.

Innovation & Management Review
Emerald Publishing Limited
2515-8961
DOI 10.1108/INMR-03-2022-0031

transform innovative activities into performance. These factors include but are not limited to the organizational structure, market orientation, culture and management philosophy, cross-functional integrations, industry, and environment (Tellis, Prabhu, & Chandy, 2009; Song, MontoyaWeiss, & Schmidt, 1997; Lukas & Ferrell, 2000; Bertrand-Cloodt, Hagedoorn, & Van Kranenburg, 2011; Belderbos, Leten, & Suzuki, 2013). However, these factors are not independent but influence every stage of the profit-transforming procedure. When the procedure begins, valuable resources are input to innovative activities, including invention and innovation, which result in creative outputs of different dimensions. The former is often tested by patent numbers that are granted by the local government, whereas the latter is often measured by new drug approvals (NDAs) in the pharmaceutical industry. After that, the valuable resources flow to the market promotion, which is the last and crucial stage to generate profits.

While extensive literature has evaluated the essential factors of the profit-generating process, this study focuses on the value of R&D outputs in the three stages of profit-making in the Chinese pharmaceutical industry, including invention, innovation and commercialization. For the innovation stage, most studies that focused on developed countries tested the new molecular entities, which mean testing the drugs that contain an active moiety that has never been approved to use in the market. Meanwhile, developing countries (for example, China and India) choose the “follow-up” strategy (Zhou & Zhou, 2017; Li, Chen, & Shapiro, 2010), which means that the innovation mostly results in generic drugs. The R&D costs increased by 80% and the number of New Chemical Entities on the market decreased by 43% from 1998 to 2008 (Federsel, 2010). The tendency leads to a more crucial status of commercialization for the Chinese pharmaceutical firms since more efforts are needed to promote the products that already exist. This analysis first examines the relationship of different factors in the three separate stages of the product life cycle, and finally offers a holistic evaluation. Building a group of simultaneous models enables the research to approach to the true value of innovation activities in China’s pharmaceutical industry. This study aims to provide a new perspective for the efficient evaluation of innovation and market activities for pharmaceutical firms in developing countries.

While all the firms realize the importance of the ability to develop and accumulate internal advantages (Xu, 2015; Artz, Norman, Hatfield, & Cardinal, 2010), the complex process of a drug’s life cycle and the spread of pharmaceutical knowledge are undervalued in the literature. This study proposes that there will be some disturbance terms between R&D inputs and outputs and between R&D and performance.

Methods

Research setting

The objective of this study was to better understand the efficiency of the pharmaceutical industry in China and evaluate the real value of patents and NDAs. We conducted our research using the listed pharmaceutical firms.

Sample and data source

We extracted firm financing data from the annual reports provided by the Shanghai Stock Exchange (www.sse.com.cn) and the Shenzhen Stock Exchange (www.szse.cn). We adjusted these data by deflating them using the 2009 GDP index. The data are comprised of 30 Chinese pharmaceutical firms over a period of eight years from 2009 to 2016 (240 observations). Firms were included whose main business was chemical medicine (21 firms) and traditional Chinese medicine (9 firms). The ranking of the 30 firms is based on the top 100 pharmaceutical enterprises in 2016 announced by the Ministry of industry information technology of China. The sample period of 2009–2016 was adopted on account of the data availability.

Statistical analysis

Stochastic frontier analysis is currently a common practice for performance evaluation modeling. It combines multiple inputs and outputs in a performance model, and it provides an indicator relative to the optimal performance measure that a firm can achieve (Assaf, Oh, & Tsionas 2017). The frequentist theory (e.g. maximum likelihood) is commonly used to estimate the SF model. However, the Bayesian approach has more flexibility in estimating SF models, especially in more complicated and robust models, such as the dynamic or random SF models (Tsionas & Kumbhakar, 2014). The adjusted variables were described in Table 1, where currency units are expressed in ¥1,000 Renminbi and are converted by the GDP deflator at 2009 prices. Several of the variables, including profit margin, R&D intensity, R&D staff intensity, sales staff intensity, market input intensity and staff quality were transformed because of the error term skewness problem.

Variables

Invention. The measurement that represents the inventions by a firm was the number of patents granted to a firm each year. Patents are normally used as a measure of inventions (Chen & Chang, 2010; Dai, Li, & Zhang 2013).

Table 1. Descriptive statistics of the measurements

Variables	Description	Minimum	Maximum	Mean	Standard deviation
logPM	Logarithm of net profit margin*, measured by dividing net profits by business income	−0.87	1.72	1.30	0.27
trend	Trend variable	1.00	8.00	4.50	2.29
$trend^2$	Square trend	1.00	64.00	25.50	21.13
logPT	Logarithm of the number of patents granted	0.00	2.94	1.29	0.70
logPA	Logarithm of the number of new drugs approved by China's FDA[a]	0.00	1.17	0.87	0.54
logRDI	Logarithm of R&D[b] intensity (R&D input*/business income*)	−1.31	1.20	0.28	0.49
logRSI	Logarithm of R&D staff intensity (number of R&D staff/number of total staff)	0.42	1.70	1.08	0.23
logSSI	Logarithm of sales staff intensity (number of sales staff/number of total staff)	0.07	1.79	1.28	0.45
logMII	Logarithm of market input intensity (Market input/business income)	0.43	1.65	1.16	0.32
logSQ	Logarithm of the staff quality (number of staff that has a college degree or above/ number of total staff)	1.28	1.97	1.72	0.13
Ownership	Dummy variable that is one if it is a state-owned firm and zero otherwise	0.00	1.00	0.40	0.49
Kinds of products	Dummy variable that is one if it is a firm that mainly produces chemical drugs and zero if it is a TCM[c]	0.00	1.00	0.70	0.46
Location	Dummy variable that is one if it is a coastal firm[d] and zero otherwise	0.00	1.00	0.67	0.47

Note(s): a: China FDA: China Food and Drug Administration
b: R&D: research and development
c: TCM: traditional Chinese medicine
d: Coastal location refers to the pharmaceutical firm's location in the coastal provinces of China, including Liaoning, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi and Hainan
*R&D input, business income and net profit in Renminbi are measured using constant prices 2009 = 100

Innovation. Innovation outcomes are measured as the total number of NDAs for firm *i* each year (DiMasi, Grabowski, & Hansen, 2016), including six subclass chemicals of NDAs and nine d subclass ones for traditional Chinese medicine (TCM) approved by the Center for Drug Evaluation of China.

Marketing evaluation. Marketing activities are measured as the profit margin for firm *i* each year (Boso, Donbesuur, Bendega, Annan, & Adeola, 2017; Vorhies & Morgan, 2005; Katsikeas, Morgan, Leonidou, & Hult, 2016).

Performance. To identify the business performance of a firm, this study selected profit margin as the main business performance indicator (Morgan, Slotegraaf, & Vorhies, 2009).

R&D intensity and R&D staff intensity. R&D intensity (i.e. expenditures on R&D divided by sales) is included as a control variable because several researchers have demonstrated an inherent relationship between R&D intensity and firm performance (King, Slotegraaf, & Kesner, 2008; Vorhies & Morgan, 2005; Jeon, Hong, Ohm, & Yang, 2015). R&D staff intensity is also used, which is measured by dividing the number of R&D staff by the total number of staff.

Market input intensity and sales staff intensity. Following the previous literature, the effect of market inputs is adopted as in the work of Situmeang and Leenders (Situmeang, Leenders, & Wijnberg, 2017).

Staff quality. Consistent with the previous studies (Ziyae, 2016), educational level is chosen to measure the staff quality.

Kind of drugs mainly produced. There are many differences between chemical drugs and TCM drugs. For example, differences exist in the active ingredient, dosage, the disease focus, and cultural and social customs. If the firm's main products are chemical medicines, the dummy variable is equal to 1.

Ownership and location of the firm. Different effects of the ownership and the location have been documented in the literature. In this study, ownership and location are the operational characteristics of a firm. When majority ownership is controlled by the state, the dummy variable is equal to 1. If the location of a firm is in a coastal area, the dummy variable is equal to 1.

Three-stage BSFA models

The performance evaluation method of the Bayesian stochastic frontier model was introduced by Broeck, Koop (Broeck, Koop, Osiewalski, & Steel, 1992). The Bayesian method in the application of SF models has been commonly adopted by researchers (Griffin & Steel, 2007). We focus here on a simple production function framework. The stochastic frontier production function includes two items, one for random noise and another for technical inefficiency. It can be expressed as

$$\mathrm{Y_{it}} = \alpha + \mathrm{X}'_{\mathrm{it}}\beta_i + \nu_{it} - \mu_{it} \quad \mathrm{i} = 1, 2, \cdots, N. \quad \mathrm{t} = 1, 2, \cdots, T. \tag{1}$$

where $\mathrm{Y_{it}}$ is the output, $\mathrm{X}'_{\mathrm{it}}$ is a k $\times$ 1 vector of inputs and other explanatory variables, β_i is a k $\times$ 1 vector of parameters, and α is a non-random intercept. ν_{it} is a measurement error distributed as ν_{it} ~N(0, σ_ν^2), and the technical inefficiency is distributed as μ_{it} ~N(0, σ_ν^2).

Four models are used for the estimations. To observe multiple variables for each firm, variables and firm dummy variables are included in the following equations:

$$\begin{aligned}\mathrm{logPT_{it}} = {} & \beta_0 + \beta_1\mathrm{trend} + \beta_2\mathrm{trend}^2 + \beta_3\mathrm{logRDI_{it}} + \beta_4\mathrm{logRSI_{it}} + \beta_5\mathrm{logSQ_{it}} + \beta_6\mathrm{ownership_{it}} \\ & + \beta_7\mathrm{kinds_{it}} + \beta_8\mathrm{location_{it}} + \nu_{it} - \mu_{it}\end{aligned} \tag{2}$$

$$\text{logPA}_{\text{it}} = \beta_0 + \beta_1\text{trend} + \beta_2\text{trend}^2 + \beta_3\text{logRDI}_{\text{it}} + \beta_4\text{logRSI}_{\text{it}} + \beta_5\text{logSQ}_{\text{it}} + \beta_6\text{ownership}_{\text{it}} + \beta_7\text{kinds}_{\text{it}} + \beta_8\text{location}_{\text{it}} + \nu_{it} - \mu_{it} \tag{3}$$

$$\text{logPM}_{\text{it}} = \beta_0 + \beta_1\text{trend} + \beta_2\text{trend}^2 + \beta_3\text{logSSI}_{\text{it}} + \beta_4\text{logMI}_{\text{it}}\text{I} + \beta_5\text{logSQ}_{\text{it}} + \beta_6\text{ownership}_{\text{it}} + \beta_7\text{kinds}_{\text{it}} + \beta_8\text{location}_{\text{it}} + \nu_{it} - \mu_{it} \tag{4}$$

$$\text{logPE}_{\text{it}} = \beta_0 + \beta_1\text{trend} + \beta_2\text{trend}^2 + \beta_3\text{logRDI}_{\text{it}} + \beta_4\text{logRSI}_{\text{it}} + \beta_5\text{logSSI}_{\text{it}} + \beta_6\text{logMII}_{\text{it}} + \beta_7\text{logSQ}_{\text{it}} + \beta_8\text{ownership}_{\text{it}} + \beta_9\text{kinds}_{\text{it}} + \beta_{10}\text{location}_{\text{it}} + \nu_{it} - \mu_{it} \tag{5}$$

We assumed a Normal distribution for the observed number of firms and set the initial value of the efficiency score to be 0.60, according to the previous studies (Peng, Duysters, & Sadowski, 2016; Li & Hamblin, 2016). We used Markov chain Monte Carlo (MCMC) simulation with 10,000 iterations and a burn-in period of 20,000. Then Geweke's diagnostic is used to check MCMC convergence (Geweke, 1991) (see Figure 1).

Results

The parameter of three-stage BSFA models

Table 2 provides the average posterior technical efficiency scores provided by the parameters of the four models. To estimate the hypotheses and further analyze efficiency, the parameters are analyzed in terms of driving efficiency at different destinations. Since the output is constant, a negative coefficient indicates a decrease in the technical inefficiency term μ_{it}, and thus a negative coefficient indicates a positive impact on technical efficiency.

The R&D expenditures are positively related to the number of patents (−0.36) and negatively related to the number of NDAs (0.34). NDAs bring the firm more profits (−0.08), but more patents are not directly related to a firm's performance (0.00, no significant). Among the models, the educational level of staff is positively related to the number of NDAs (−0.13), but not directly related to the performance (not significant), and the significant terms indicate that R&D staff intensity is negatively related to both NDAs (0.43) and firm performance (0.2). H3 states that the market inputs are positively related to performance, including sales expenditures and sales staff. The hypothesis is not supported since the related parameters are not statistically significant.

State-owned is negatively associated with patents, the NDAs, and the firm's performance (−0.23, −0.22, and −0.24, respectively). Chemical drug firms are superior to TCM firms on

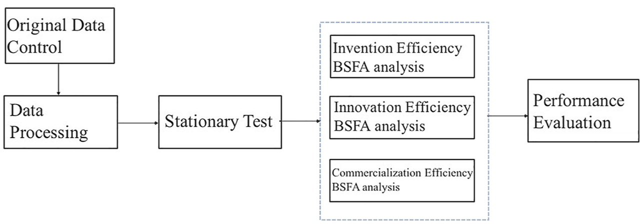

Figure 1. Flowchart of the proposed methodology

Table 2. Parameter estimates of the three-stage BSFA model

	Model 1 Invention	Model 2 Innovation	Model 3 Commercialization	Model 4 Performance evaluation
Output	logPT	logPA	lgPM	lgPE
Independent variables				
Constant	2.06* (0.70)	1.89* (0.45)	1.47* (0.19)	1.49* (0.19)
Trend	0.17* (0.07)	0.00 (0.06)	−0.01 (0.02)	−0.00 (0.02)
Trend-sqr.	−0.01 (0.01)	−0.00* (0.01)	0.00 (0.00)	0.00 (0.00)
logPT				0.00 (0.01)
logPA				−0.08* (0.03)
logRDI	−0.36* (0.10)	0.34* (0.08)		0.00 (0.04)
logRSI	0.26 (0.17)	0.43* (0.14)		0.20* (0.07)
logSSI			0.08 (0.04)	0.04 (0.05)
logMII			0.01 (0.04)	0.11 (0.06)
logSQ	−0.52 (0.36)	−0.76* (0.24)	−0.02 (0.12)	−0.13 (0.12)
Ownership	−0.23* (0.09)	0.08 (0.07)	−0.22* (0.30)	−0.24* (0.03)
Kind	−0.06 (0.09)	0.28* (0.07)	−0.05 (0.03)	−0.03 (0.03)
Location	0.28* (0.10)	−0.20* (0.07)	0.08* (0.02)	0.04 (0.03)
DIC	−349.80	−385.10	−148.00	−223.10

Note(s): *the mean value of the parameter is significant in 95% prediction intervals. DIC refers to the deviance information criterion

performance (−0.03), and TCM firms have done better with NDAs (0.28). The location is a crucial factor for firms in China, as the coastal area is deemed to develop faster and better. Coastal firms obtain more NDAs (−0.2) and fewer patents (0.28), but this is not significantly related to performance.

Discussion and conclusion

We aim in this study to extend the existing literature by focusing on several important contributions. First, in this study, the product life-cycle is decomposed into three stages (invention, innovation and commercialization) to be analyzed at a micro level and then analyzed as a whole. The breakdown of these three stages provides a more granular analysis of the relationship. Second, several interesting relationships are revealed. R&D input (including expenditures and human resources) is negatively related to the number of NDAs and firm performance. State-owned firms have a better performance and have more patents granted than private-owned firms in China. The TCM firms generate more new drugs than the chemical drug firms generate. Third, Bayesian stochastic frontier analysis (BSFA) is used to estimate the efficiency and performance of firms and is rarely used in China's pharmaceutical industry.

As assumed, R&D spending was positively related to patents, but not directly related to performance. This result is in line with those with a strong research basis who presented that in-house research capabilities are a key factor for a firm to generate new products (Jensen, Thomson, & Yong, 2011; Bogner & Pratima, 2007). Therefore, a firm's R&D input can be seen as a very good predictor of its future patent output and is assumed to generate more new products to earn profit back. However, patents are not always targeted at specific products, especially for listed companies. If the firm's focus is on quantity, a patent competition, or competitors' obstacles rather than on patents that better meet market needs (Artz *et al.*, 2010; Scannell & Bosley, 2016), the results found in the present paper would show that the number of patents is not directly related to performance. According to the patent data, we have found that most of the patents are not radical in China's pharmaceutical firms, which mainly consist of drug preparation methods, a new technique to improve the production, or appearance design. Thus, in China's pharmaceutical industry, most of the patents are not creative enough to increase profit margins and lack the combination of the firm's unique resources.

The hypothesis was also supported and found that NDAs would be positively related to performance. This result is consistent with previous studies (Dai *et al.*, 2013) and suggests that firms keep generating and introducing new products into the market in order to achieve higher performance and enjoy brief monopoly profits from each of the new products that is introduced into the market. In addition, new drugs as the driving force of marketing effectively reduce competition in the industry and thus gain more sales and profits (Wang & Lestari, 2013).

While R&D input (including expenditures and human resources) is positively related to patents, it is negatively related to the number of NDAs. There might be some reasons. First, the number of new drugs approved per billion US dollars spent on R&D has halved roughly every 9 years since 1950. Thus, adding human resources and other resources to R&D have become a tendency, thus leading to a rise in R&D spending in major companies and for the industry overall (Scannell, Blanckley, Boldon, & Warrington, 2012). Second, complex clinical studies for drug approvals need higher expenditures. Finally, with the increasing R&D spending, the additional funds are likely to flow into basic research, which may lead to a reduction in new products. The increasing human resources also induced inefficiency in NDAs and firms' performances, especially in low levels of quality. In this study, the objects are big Pharms that have more resources and are in a better position to innovate. However, there are some disadvantages, such as their flexibility and dynamic capabilities (Rogers, 2004). The results of R&D inputs depend on the resources they have already mastered, and on how managers can mobilize and convert them into value creation activities. (Alavi & Leidner, 2001).

An interesting finding is the positive relationship between state-owned firms and performance. While the result seems to contradict the existing evidence that state-ownership would bring inefficiencies, Boateng, Bi, and Brahma (2017) revealed that, in China, ownership concentration has a positive and significant impact on the operating performance of firms. Other empirical evidence in emerging countries such as India (Boateng *et al.*, 2017; Ramaswamy, Li, & Veliyath, 2002), Singapore (Ang & Ding, 2006) and Russia (Buck, Filatotchev, Wright, & Zhukov, 1999) have supported the positive relationship between concentrated ownership and firm performance. Because of the Shareholding reform of state-owned enterprises, performance-based incentive contracts were designed to align the interest of managers with shareholders (Shen, Zhou, & Lau, 2016). Furthermore, in China, some of the medicines' prices are established by the government, which may induce a monopoly, especially in big Pharms. Approximately 20% of all medicines are priced by the state, which are mainly listed in the National Basic Medical Treatment and Insurance and Medicine Catalog. However, they receive 80% of all market income (Zhu, 2008). Coincidental with the above studies, this paper certifies the results in emerging countries, and broadens the conclusions to the pharmaceutical industry.

Despite all attention paid to the role of chemical medical firms on performance, the potential contribution of TCM firms in the Chinese pharmaceutical industry to performance has been largely ignored. TCM firms are the second largest component of the pharmaceutical industry in China with 15.0% of the whole industry sales income in 2016. Chemical medical firms are the largest component with 74.4% of the industry's sales (Ministry of Commerce of People's Republic of China, 2016). Due to the implementation of the strategic plan decreed by the government for the development of TCM, the TCM firms have gained more political resources (Li, Yu, Yang, Qi, & Ho-yingFu, 2014). Thus, the attributes of TCM for a firm may generate more new drugs.

The result of market input evaluation in this study is consistent with the finding that firms that exceed their profit goals have lower marketing expenses compared to firms that miss their goal (Bennett, Bettis, Gopalan, & Milbourn, 2017), and costs may outweigh the benefits obtained from market spending (Malshe & Biemans, 2014).

It was also found that the staff intensity is positively related to NDAs. These results are consistent with previous studies that high staffing enhances the creativity and demand for innovation (Ziyae, 2016). Furthermore, researchers suggest that firms that can improve the educational levels of employees enjoy higher level of performance (Hinkin & Bruce Tracey, 2010; Kehoe & Wright, 2013). Moreover, the improved performance that may result in higher level staff quality.

Also interesting is the finding that the coastal location is positively related to firm's performance, as also shown in previous research. However, it is negatively related to the number of NDAs. There are several policies for non-coastal areas, especially for the west of China, including "Some opinions on strengthening the scientific and technological work in the development of the Western China" and "The 10th five-year plan for the development of high technology industry". Western firms obtain more subsidies for R&D and more support in drug registration, but they lack access to knowledge and capable people, thus still resulting in lower profit margins.

Based on the results of the performance evaluation, it is revealed that there are no common factors among Chinese pharmaceutical firms except for ownership, and each firm is driven by its own situation. Some firms decrease their efficiency, while others increase it. This heterogeneous behavior indicates that there is no common factor for enhancing the efficiency of all Chinese pharmaceutical firms. Therefore, similar measures for changes do not exist. Each firm should focus on their own advantages and remaining efficient, reacting quickly to changing market demands with new products.

Limitation and future research

Three main limitations of this study also point to future research opportunities. First, the timescale is relatively short. It is mainly a result of a narrow set of pharmaceutical firms listed on the China Stock Market and their short period of quoting. However, the Bayes theorem allows using less data, and the OpenBUGS (software) creates a compiled code to perform a Markov chain Monte Carlo (MCMC) algorithm for sampling from the posterior distribution (Griffin & Steel, 2007). Second, the sample was limited to the pharmaceutical industry in a single country, and such conclusions only apply to China. Therefore, more fine-gained data need to be examined in future empirical research to reach a better understanding of the innovation activities and firm performance.

Finally, this study assumes that patents or new drug approvals owned by firms means that firms are using them effectively. However, firms may be different when using these R&D outputs, depending on the value and environmental opportunities. For instance, patents or new drug approvals as indicators for performance may well be subject to the firm's ability to transfer knowledge to practical skills and finally to profits, and to the integration of knowledge from different areas. In addition, recent research in China revealed that firms are faced with different resource allocations that are determined by government based on where the firm is located (Jin, Lei, & Yu, 2016). Therefore, more organizational and environmental factors need to be considered in future empirical research to reach to a better understanding of the innovation activities and firm performance.

Abbreviations

NDAs	new drug approvals
R&D	research and development
TCM	traditional Chinese medicine
BSFA	Bayesian stochastic frontier analysis

References

Alavi, M., & Leidner, D. E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS Quarterly*, *25*(1), 107–36. doi: 10.2307/3250961.

Ang, J. S., & Ding, D. K. (2006). Government ownership and the performance of government-linked companies: The case of Singapore. *Journal of Multinational Financial Management*, *16*(1), 64–88. doi: 10.1016/j.mulfin.2005.04.010.

Artz, K. W., Norman, P. M., Hatfield, D. E., & Cardinal, L. B. (2010). A longitudinal study of the impact of R&D, patents, and product innovation on firm performance. *Journal of Product Innovation Management*, *27*(5), 725–40. doi: 10.1111/j.1540-5885.2010.00747.x.

Assaf, A. G., Oh, H., & Tsionas, M. (2017). Bayesian approach for the measurement of tourism performance: A case of stochastic frontier models. *Journal of Travel Research*, *56*(2), 172–86. doi: 10.1177/0047287516633528.

Belderbos, R., Leten, B., & Suzuki, S. (2013). How global is R&D? Firm-Level determinants of home-country bias in R&D. *Journal of International Business Studies*, *44*(8), 765–86. doi: 10.1057/jibs.2013.33.

Bennett, B., Bettis, J. C., Gopalan, R., & Milbourn, T. (2017). Compensation goals and firm performance. *Journal of Financial Economics*, *124*(2), 307–30. doi: 10.1016/j.jfineco.2017.01.010.

Bertrand-Cloodt, D., Hagedoorn, J., & Van Kranenburg, H. (2011). The strength of R&D network ties in high-tech sectors – a multi-dimensional analysis of the effects of tie strength on innovation performance. *Technology Analysis and Strategic Management*, *23*(10), 1015–30. doi: 10.1080/09537325.2011.621294.

Bettis, R. A., & Hitt, M. A. (1995). The new competitive landscape. West sussex. *Strategic Management Journal*, *16*(1), 7–19. doi: 10.1002/smj.4250160915.

Boateng, A., Bi, X. G., & Brahma, S. (2017). The impact of firm ownership, board monitoring on operating performance of Chinese mergers and acquisitions. *Review of Quantitative Finance and Accounting*, *49*(4), 925–48. doi: 10.1007/s11156-016-0612-y.

Bogner, W. C., & Pratima, B. (2007). Knowledge management as the basis of sustained high performance. *Journal of Management Studies*, *44*(1), 165–88. doi: 10.1111/j.1467-6486.2007.00667.x.

Boso, N., Donbesuur, F., Bendega, T., Annan, J., & Adeola, O. (2017). Does organizational creativity always drive market performance?. *Psychology and Marketing*, *34*(11), 1004–15. doi: 10.1002/mar.21039.

Broeck, J. V. D., Koop, G., Osiewalski, J., & Steel, M. F. J. (1992). Stochastic frontier models ☆: A bayesian perspective. *Journal of Econometrics*, *61*(2), 273–303. doi: 10.1016/0304-4076(94)90087-6.

Buck, T., Filatotchev, I., Wright, M., & Zhukov, V. (1999). Corporate governance and employee ownership in an economic crisis: Enterprise strategies in the former USSR. *Journal of Comparative Economics*, *27*(3), 459–74. doi: 10.1006/jcec.1999.1606.

Chen, Y.-S., & Chang, K.-C. (2010). Exploring the nonlinear effects of patent citations, patent share and relative patent position on market value in the US pharmaceutical industry. *Technology Analysis and Strategic Management*, *22*(2), 153–69. doi: 10.1080/09537320903498496.

Dai, Y., Li, M., & Zhang, T. (2013). Innovation performance of Chinese pharmaceutical industry patents based on fuzzy comprehensive evaluation. *Journal of Investigative Medicine*, *61*(4), S26–S7.

DiMasi, J. A., Grabowski, H. G., & Hansen, R. W. (2016). Innovation in the pharmaceutical industry: New estimates of R&D costs. *Journal of Health Economics*, *47*, 20–33. doi: 10.1016/j.jhealeco.2016.01.012.

Federsel, H.-J. (2010). Process R&D under the magnifying glass: Organization, business model, challenges, and scientific context. *Bioorganic and Medicinal Chemistry*, *18*(16), 5775–94. doi: 10.1016/j.bmc.2010.06.029.

Geweke, J. (1991). Evaluating the accuracy of sampling-based approaches to the calculation of posterior moments. *Staff Report*, *4*, 169–93.

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic Management Journal*, *17* (2), 109–22. doi: 10.1002/smj.4250171110.

Griffin, J. E., & Steel, M. F. J. (2007). Bayesian stochastic frontier analysis using WinBUGS. *Journal of Productivity Analysis*, *27*(3), 163–76. doi: 10.1007/s11123-007-0033-y.

Hinkin, T. R., & Bruce Tracey, J. (2010). What makes it so great? An analysis of human resources practices among fortune's best companies to work for. *Cornell Hospitality Quarterly*, *51*(2), 158–70. doi: 10.1177/1938965510362487.

Jensen, P. H., Thomson, R., & Yong, J. S. (2011). Estimating the patent premium: Evidence from the Australian inventor survey. *Strategic Management Journal*, *32*(10), 1128–38. doi: 10.1002/smj.925.

Jeon, J., Hong, S., Ohm, J., & Yang, T. (2015). Causal relationships among technology acquisition, absorptive capacity, and innovation performance: Evidence from the pharmaceutical industry. *PLoS One*, *10*(7), e0131642. doi: 10.1371/journal.pone.0131642.

Jin, X., Lei, G., & Yu, J. (2016). Government governance, executive networks and enterprise R&D Expenditure. *China Journal of Accounting Research*, *9*(1), 59–81. doi: 10.1016/j.cjar.2015.09.001.

Katsikeas, C. S., Morgan, N. A., Leonidou, L. C., & Hult, G. T. M. (2016). Assessing performance outcomes in marketing. *Journal of Marketing*, *80*(2), 1–20. doi: 10.1509/jm.15.0287.

Kehoe, R. R., & Wright, P. M. (2013). The impact of high-performance human resource practices on employees' attitudes and behaviors. *Journal of Management*, *39*(2), 366–91. doi: 10.1177/0149206310365901.

King, D. R., Slotegraaf, R. J., & Kesner, I. (2008). Performance implications of firm resource interactions in the acquisition of R&D-Intensive firms. *Organization Science*, *19*(2), 327–40. doi: 10.1287/orsc.1070.0313.

Li, X., & Hamblin, D. (2016). Factors impacting on cleaner production: Case studies of Chinese pharmaceutical manufacturers in Tianjin, China. *Journal of Cleaner Production*, *131*, 121–32. doi: 10.1016/j.jclepro.2016.05.066.

Li, J., Chen, D., & Shapiro, D. M. (2010). Product innovations in emerging economies: The role of foreign knowledge access channels and internal efforts in Chinese firms. *Management and Organization Review*, *6*(2), 243–66. doi: 10.1111/j.1740-8784.2009.00155.x.

Li, F., Yu, K. F., Yang, J., Qi, Z., & Ho-ying Fu, J. (2014). Authentic leadership, traditionality, and interactional justice in the Chinese context. *Management and Organization Review*, *10*(2), 249–73. doi: 10.1111/more.12027.

Lukas, B. A., & Ferrell, O. C. (2000). The effect of market orientation on product innovation. *Journal of the Academy of Marketing Science*, *28*(2), 239–47. doi: 10.1177/0092070300282005.

Malshe, A., & Biemans, W. (2014). The role of sales in NPD: An investigation of the US health-care industry. *Journal of Product Innovation Management*, *31*(4), 664–79. doi: 10.1111/jpim.12159.

Ministry of Commerce of People's Republic of China (2016). *Statistical Analysis Report on the Operation of Drug Circulation Industry in 2016*, Ministry of Commerce of People's Republic of China.

Morgan, N. A., Slotegraaf, R. J., & Vorhies, D. W. (2009). Linking marketing capabilities with profit growth. *International Journal of Research in Marketing*, *26*(4), 284–93. doi: 10.1016/j.ijresmar.2009.06.005.

Peng, H., Duysters, G., & Sadowski, B. (2016). The changing role of guanxi in influencing the development of entrepreneurial companies: A case study of the emergence of pharmaceutical companies in China. *The International Entrepreneurship and Management Journal*, *12*(1), 215–58. doi: 10.1007/s11365-014-0323-6.

Ramaswamy, K., Li, M., & Veliyath, R. (2002). Variation in ownership behavior and propensity to diversify: A study of the Indian context. *Strategic Management Journal*, *23*(4), 345–58. doi: 10.1002/smj.227.

Rogers, M. (2004). Networks, firm size and innovation. *Small Business Economics*, *22*(2), 141–53. doi: 10.1023/b:sbej.0000014451.99047.69.

Scannell, J. W., & Bosley, J. (2016). When quality beats quantity: Decision theory, drug discovery, and the reproducibility crisis. *PLoS One*, *11*(2), 21. doi: 10.1371/journal.pone.0147215.

Scannell, J. W., Blanckley, A., Boldon, H., & Warrington, B. (2012). Diagnosing the decline in pharmaceutical R&D efficiency. *Nature Reviews Drug Discovery*, *11*(3), 191–200. doi: 10.1038/nrd3681.

Shen, W., Zhou, Q., & Lau, C.-M. (2016). Empirical research on corporate governance in China: A review and new directions for the future. *Management and Organization Review*, *12*(1), 41–73. doi: 10.1017/mor.2015.11.

Situmeang, F. B. I., Leenders, M., & Wijnberg, N. M. (2017). New product performance and the benefit of periodically changing the relative influence balance between marketing and R&D. *Journal of Business and Industrial Marketing*, *32*(1), 180–91. doi: 10.1108/jbim-01-2015-0020.

Song, X. M., MontoyaWeiss, M. M., & Schmidt, J. B. (1997). Antecedents and consequences of cross-functional cooperation: A comparison of R&D, manufacturing, and marketing perspectives. *Journal of Product Innovation Management*, *14*(1), 35–47. doi: 10.1111/1540-5885.1410035.

Tellis, G. J., Prabhu, J. C., & Chandy, R. K. (2009). Radical innovation across nations: The preeminence of corporate culture. *Journal of Marketing*, *73*(1), 3–23. doi: 10.1509/jmkg.73.1.3.

Tsionas, E. G., & Kumbhakar, S. C. (2014). Firm heterogeneity, persistent and transient technical inefficiency: A generalized true random-effects model. *Journal of Applied Econometrics*, *29*(1), 110–32. doi: 10.1002/jae.2300.

Vorhies, D. W., & Morgan, N. A. (2005). Benchmarking marketing capabilities for sustainable competitive advantage. *Journal of Marketing*, *69*(1), 80–94. doi: 10.1509/jmkg.69.1.80.55505.

Wang, K.-J., & Lestari, Y. D. (2013). Firm competencies on market entry success: Evidence from a high-tech industry in an emerging market. *Journal of Business Research*, *66*(12), 2444–50. doi: 10.1016/j.jbusres.2013.05.033.

Xu, S. (2015). Balancing the two knowledge dimensions in innovation efforts: An empirical examination among pharmaceutical firms. *Journal of Product Innovation Management*, *32*(4), 610–21. doi: 10.1111/jpim.12234.

Zhou, S. J., & Zhou, A. J. (2017). Research potential on innovation in India and China. *Management and Organization Review*, *13*(2), 447–9. doi: 10.1017/mor.2017.15.

Zhu, H. (2008). Defects in the medical system and distortion in drug pricing. *Social Sciences in China*, *29*(01), 50–65. doi: 10.1080/02529200801920806.

Ziyae, B. (2016). Presenting an evaluation model of human resource management's effect on corporate entrepreneurship. *Journal of Organisational Studies and Innovation*, *3*(2), 1–15. doi: 10.1108/wjemsd-03-2016-0013.

Corresponding author
Dan Li can be contacted at: romearmy@163.com