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Economics and Finance Readings

Asia-Pacific Conference on Economics and Finance, 2023

Springer

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Evan Lau · Widya Paramita · Kai-Hong Tee · Lee Ming Tan
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Preface

The Asia Pacific Conference of Economics and Finance (APEF 2023) was held on December 14–15, 2023, at the Holiday Inn Singapore Atrium. Researchers from a wide array of countries, including Cambodia, China, Czechia, Germany, Hong Kong, India, Indonesia, Ireland, Japan, the Netherlands, New Zealand, Polska, Philippines, Singapore, South Africa, Taiwan, U.A.E, UK, and the United States, presented a total of 42 research papers. The conference included keynote presentations from Denise Cheok, Assistant Director at APAC Economist, Moody's Analytics, Singapore, who discussed 'APAC Outlook: Holding Firm', and Dr. Kai-Hong Tee from Loughborough University, UK, who presented on 'Hedge fund inceptions and market competition'.

This book presents a curated selection of 14 outstanding papers that were showcased at APEF 2023, providing readers with profound insights into a wide spectrum of economics and finance topics. Collectively, these papers offer a comprehensive overview of the key challenges and opportunities shaping the economic and financial landscape of the Asia Pacific, making a valuable contribution to the discourse on regional development and policy formulation.

APEF 2024 will be held in person on December 12–13, 2024, at the Holiday Inn Singapore Atrium. For more information about the conference, please visit APEF.ear.com.sg. You are warmly invited to participate, and I eagerly anticipate your involvement.

Kota Samarahan, Malaysia

Prof. Dr. Evan Lau
APEF 2023 Conference Chair

East Asia Research (EAR)

EAR academic conferences provide a meaningful platform for researchers, post-graduates, academicians, and industry practitioners to share unique insights and drive innovation. This is a great opportunity for expanding contact networks beyond a singular field and kick-starting a strategic collaboration. Such partnership can bridge the resources and expertise of multiple disciplines to spearhead pioneer movements, giving rise to breakthroughs in long-standing issues.

Contents

About the Editors

Evan Lau currently serving as Deputy Dean of Research and Commercialization at Universiti Malaysia Sarawak (UNIMAS), is a distinguished academic with a rich background in economics, finance, and business. Throughout his career at UNIMAS, he has held various pivotal roles including Deputy Dean for Research and Postgraduate, Director of the Centre for Business, Economics and Finance Forecasting (BEFfore), and Head of Strategy. Internationally recognized for his scholarly work, Evan has held visiting positions at prestigious institutions such as the University of Cambridge and several universities in Indonesia. Notably, he was twice selected for the World Class Professor (WCP) program by the Ministry of Education and Culture in Indonesia (2020 and 2021) and appointed as a Visiting Research Fellow for the Central Bank of Malaysia in May 2021. Evan's research prowess is evidenced by his extensive publication record, which includes 108 journal articles and 91 research papers across various mediums. He has received numerous accolades for his research excellence, including the Young Researcher Award at UNIMAS, research medals from Research Expos, and the Highest-Impact Journal Paper Award. As an active researcher, Evan has secured 35 research grants and has supervised a significant number of postgraduate and undergraduate research projects. His contributions to academia extend beyond UNIMAS, with his participation as a speaker at international conferences in several countries including Indonesia, UAE, Sri Lanka, Italy, India, Philippines, China, and Malaysia. Evan's impact on the field of economics is recognized internationally, with his inclusion among the Top 9% of economists in Malaysia and ASEAN, as well as the Top 10% in Asia by the Research Papers in Economics (RePEc) network. Additionally, he is among the highly cited authors at UNIMAS. Outside of academia, Evan maintains a passion for running and traveling. His multifaceted achievements and dedication to research excellence and academic leadership underscore his significant contributions to the field, bringing sustainable impact to academia and beyond.

Widya Paramita is an Assistant Professor and is currently the Head of Publication Unit in Faculty of Economics and Business at Universitas Gadjah Mada. Publication Unit manages two international journals: Journal of Indonesian Economy and

Business (Scopus-indexed) and Journal of Leadership in Organizations. Simultaneously, she has been serving as the Editor-in-chief of Journal of Indonesian Economy and Business. She has approximately 30 pieces of publications related to consumer behavior, social marketing, ethical decision-making, organizational leadership, and entrepreneurship in reputable journals such as Journal of Business Ethics, Journal of Business Research, Journal of Business Venturing Insights, Journal of Retailing and Consumer Services, Marketing Letters, International Journal of Advertising, Australasian Marketing Journal amongst others. Simultaneously, she has been an ad-hoc reviewer for several journals such as Global Journal of Fashion Marketing, Australasian Marketing Journal, International Journal of Retail and Distribution Management. Due to her involvement in research, she received the best publication award in Social Science from Universitas Gadjah Mada.

Kai-Hong Tee is currently a Senior Lecturer in Finance at Loughborough University School of Business and Economics in the UK. He has worked previously as a Lecturer in Finance at the University of Aberdeen and as a Property Investment Marketing Consultant on both residential and commercial sectors in the international properties markets based in Singapore. His research interests include the application of asymmetric risk measures on portfolio optimization, the study of liquidity risks, and efficient performance of managed futures and hedge funds. Dr. Tee's research has been published in reputable Journals such as the European Journal of Operational Research, Journal of Empirical Finance, Quantitative Finance and European Financial Management. He has a B.A. in Economics and Mathematics from the National University of Singapore, an M.B.A. (with distinction) in finance from the Leeds University Business School, and a Ph.D. in Finance from Heriot-Watt University in Edinburgh, Scotland.

Mr. Lee Ming Tan is the founder of East Asia Research and he obtained his Master of Applied Finance from the University of Adelaide. He is deeply interested in how humans function and react with each other. An insight into how people's minds think and how they work together is invaluable in just about every field. Outside of work, Anthony Tan enjoys outdoor activities and occasional computer games.

Research on the Relationship Between Innovation Openness, R&D Investment and Innovation Performance of Manufacturing Enterprises

Xu Jianzhong and Wang Yanxia

Abstract The panel data of 2,768 Shanghai and Shenzhen A-share manufacturing listed companies from 2011 to 2021 was analyzed, on the influence of innovation openness on innovation performance, the mediating effect of R&D investment and the moderating effect of innovation efficiency on R&D investment are empirically studied. The results show that innovation openness positively affects R&D investment and innovation performance. Research and development investment has a positive effect on innovation performance, and plays a partial mediating role between innovation openness and innovation performance. Meanwhile, innovation efficiency positively affects the relationship between R&D investment and innovation performance, and partially mediates the role of R&D investment in innovation openness and innovation performance.

Keyword Innovation openness · R&D investment · Innovation efficiency · Innovation performance

1 Introduction

In recent years, Chinese manufacturing enterprises participation in the division of labor among countries in the world is constantly increasing, previously, we could rely on developed countries, consciously or unconsciously, to transfer or spread their technology to improve the productivity of manufacturing companies, but now this driving

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effect almost reaches the "threshold value", and Chinese manufacturing enterprises are in trouble (Lv et al., 2018; Yang et al., 2014), this has seriously affected our manufacturing enterprises to gain an advantage in international competition. Therefore, more and more enterprises realize the importance of innovation, and open innovation gradually rises. Open innovation theory can help enterprises integrate internal and external resources, explore and develop corresponding market transformation mechanisms of innovation achievements, and share and create new values (Xu et al., 2017). Since the theory of open innovation was proposed, the academic and business circles have applied it to competitive strategy, and the interaction between innovation openness and innovation performance has been discussed. The existing literature has drawn three conclusions on the relationship between them: (1) Innovation openness has a positive impact on innovation performance. Caloghirou et al. (2004) collected research data from 7 European countries and found that openness is conducive to enhancing R&D competitiveness of enterprises and improving innovation performance. Ren (2010) believes that enterprise partners can be divided into different categories, among which, when enterprises cooperate with suppliers or customers and share innovation results, the innovation openness of enterprises will improve, and the innovation performance will also improve. (2) Innovation openness negatively affects innovation performance. Gales and Mansour-Cole (1995) believes that the excessively high openness of enterprises means that enterprises will cooperate with more external partners, which is prone to a high degree of uncertainty, and such uncertainty may lead to the failure of cooperation. Wang and Di (2017) found through research that with the establishment of a favorable environment for innovation cooperation in China, more enterprises will carry out innovation cooperation activities, which may also have a negative impact due to excessive opening-up. (3) There is an inverted U-shaped relationship between innovation openness and innovation performance. Laursen and Salter (2006) selected more than 2700 manufacturing enterprises in the UK for analysis, and the results showed that although innovation openness has been improving, innovation performance will not. On the contrary, when innovation openness reaches a certain critical point, innovation performance will decrease; scholars Chen and Chen (2008) conducted research on enterprises in China and found that the more enterprises need science and technology as a driving force for development, the more critical point exists in innovation openness.

According to the relationship among innovation openness, R&D investment and innovation performance, a moderated mediation model is creatively established, and the following questions are mainly studied: ① How does innovation openness change positively promote the relationship between R&D input and innovation performance? ② How does the change in innovation openness positively affect innovation performance by influencing R&D investment? ③ Can innovation efficiency regulate the relationship between R&D input and innovation performance? ④ How does the change in innovation efficiency affect the effect of R&D input on innovation performance? Therefore, this paper selects 16,974 research data of manufacturing enterprises to carry out an empirical study, expounds the relationship between innovation openness, R&D investment and innovation performance,

enriches the methods to improve innovation performance of manufacturing enterprises, and brings enlightenment to the managers of manufacturing enterprises to conduct innovative management behavior.

2 Theoretical Analysis and Research Hypothesis

2.1 The Relationship Between Innovation Openness and Innovation Performance

The research purpose of open innovation is to promote enterprises to improve innovation performance. Chesbroug (2003) proposed the concept of open innovation for the first time and pointed out that open innovation requires organizations to integrate external and internal resources to achieve technological innovation to the greatest extent. Such technological innovation is not only reflected in breaking technical bottlenecks and accelerating product development, but also in the company's strategic cooperation and investment and other business models. It helps to improve the development ability of new products and the efficiency of technological innovation, and transform the products into important industries as soon as possible. Innovation openness is used to indicate the close degree of cooperation between an enterprise and external partners. It is a part of the open innovation theory, which was first proposed by Ahuja (2000) in 2000. In the process of expanding openness and cooperating with partners in the field of innovation, enterprises can transform external information and resources into their own competitive advantages, resist technological risks and market risks, and thus enhance their research and development ability and improve innovation performance (Gao & Ma, 2014).

Innovation performance refers to the new achievements created by an enterprise when it invests resources into the innovation system, including new products, new knowledge, new innovative thinking and applied new inventions, and those innovations that can make the enterprise gain more benefits based on the innovation achievements are defined as "successful innovations" (Shen & Wang, 2012). When cooperating with external organizations, enterprises can obtain different and diversified resources and information, and then integrate external and internal knowledge, which can help enterprises improve innovation performance (Catherine & Andrea, 2011). Chen (2016) believes that only by accepting open innovation ideas can manufacturing enterprises achieve breakthrough achievements in product innovation or the industry, which can help enterprises reduce risks and improve innovation performance. Improving innovation openness also helps to expand the scope of international cooperation of manufacturing enterprises, integrate the information and skills collected from the outside with the new resources of the enterprises in the technological innovation system, so that these enterprises can generate competitiveness, so as to produce products and services with new profits and new prices, and improve the innovation performance of manufacturing enterprises.

Yan and Cai (2014) et al. adopted structural equation model and found that there are multiple direct and indirect interaction paths between innovation openness and innovation performance; Guo (2016) took 400 enterprises in the main economic development zones of Shandong, Jiangsu, Fujian, Sichuan and Shaanxi provinces as research objects and found that innovation openness had a positive impact on absorptive capacity and innovation performance. Kline (2003) believes that if an enterprise is willing to share technological innovation results with other partners, its financial earnings can be significantly improved. Yang and Yang (2015) conducted a questionnaire survey on 232 manufacturing enterprises in the Yangtze River Delta and found that openness has a direct positive impact on enterprise innovation performance. Therefore, the improvement of innovation openness can help enterprises reduce the uncertainty caused by fierce market competition and changes in social environment, reduce various risk factors and expand market channels.

Therefore, the following hypothesis is obtained:

H1: Innovation openness has a significant positive impact on innovation performance.

2.2 Relationship Between Innovation Openness and R&D Investment

First of all, open innovation refers to the management activities that form an information exchange network within an enterprise based on the theory of information interaction and implement systematic control over information transmission across the boundaries of the enterprise (Yang & Zhao, 2020). For example, Goerzen and Beamish (2005) pointed out that collaboration located in different regions can bring important knowledge to enterprises. Secondly, the establishment and maintenance of a wide range of external cooperative relations enhance the organization's operation and management capabilities, which improve the innovation process and the efficiency of enterprise resource allocation (Gao et al., 2019). Thirdly, with the improvement of innovation openness, the number of partners will increase, so that enterprises can obtain cutting-edge technology information faster to better grasp the market dynamics and provide consumers with diversified comfortable services and convenient and useful products, so as to have more advantages in competition (Xu et al., 2019). Therefore, improving innovation openness and keeping close ties with partners in different regions can effectively help enterprises absorb advanced knowledge, improve resource allocation efficiency, speed up research and development, provide diversified products and services, and thus increase innovation performance. Only by increasing R&D investment, can enterprises have a source of funds to carry out R&D cooperation with more partners and achieve a win–win situation. If companies want to be more open to innovation, they should incorporate increased investment in R&D into their overall strategy.

Enterprises are in a dominant position in market competition. In order to follow the market trend, they need to constantly produce innovative products that can meet

the needs of the society (Zhang, 2010). Innovation is an inexhaustible force for the growth of enterprises. Scientific management of enterprises can ensure the smooth progress of innovation activities and increase the benefits of enterprises. Only by continuously conducting product research and development can an enterprise be in a leading position in the industry, and its future development cannot be separated from innovation (Chen et al., 2008). While increasing cooperation with other enterprises, we should not neglect our own innovation, including technology development and product research and development. In the process of implementing the open innovation strategy, enterprises can carry out both cooperative and independent R&D activities at the same time, whose essence is to master external information and integrate and apply corporate wisdom to produce products and services that meet customer needs (Cassiman & Valentini, 2016). Therefore, while improving the openness of innovation and strengthening cooperative research and development, enterprises should still put independent research and development in a key position of corporate strategic development and strengthen scientific management to ensure that enterprises are always in the leading position in the industry and not eliminated by the market.

Independent research and development helps enterprises gain the right to speak in the market competition; Collaborative research and development can help solve the huge investment and risk problems in research, avoid risks, reduce project development cycle, and help enterprises improve innovation performance based on complementary advantages (Faems et al., 2005). Therefore, whether it is independent research and development or cooperative research and development, it is beneficial for the long-term development of enterprises. If an enterprise wants to combine independent research and development with cooperative research and development, increasing R&D investment is an inevitable choice.

Therefore, the following hypothesis is obtained:

H2: Innovation openness has a significant positive influence on R&D investment.

2.3 The Mediating Role of R&D Investment

R&d input is an important resource support for enterprises to carry out technological innovation activities, involving a large amount of capital, talents and intangible resources, which is a concrete reflection of enterprises' emphasis on innovation (Hu et al., 2018). The impact of R&D input on innovation performance mainly includes the following three points: First, the development of an enterprise cannot be achieved without excellent R&D personnel, and R&D input is the key to ensure the quality of life of R&D personnel. Innovation practice activities carried out by an enterprise are the process of the re-creation of knowledge by R&D personnel, which is the concrete manifestation of their innovation ability (Coombs, 1996); Secondly, the amount of investment in research and development to some extent represents the importance enterprises attach to innovation, so it can be used as a means of publicity to help

enterprises get more cooperation; Thirdly, increasing R&D investment can improve the innovation and R&D capability of enterprises (Liu & Lu, 2018). With sufficient R&D investment, enterprises will have more funds to improve the working environment of employees, help R&D personnel to break through technical bottlenecks, and achieve technical achievements, so as to improve innovation performance.

Most of the existing researches on the impact of R&D input on innovation performance agree that R&D input has a significant positive impact on innovation performance. For example, Li et al. (2020) studied the panel data of 59 listed high-tech enterprises in western China from 2014 to 2018, and the results showed that with the increase in R&D investment, innovation performance would be improved correspondingly. Vancauteren (2016) conducted a study on the food processing industry and found through analysis that the larger the proportion of investment in R&D, the more patents the enterprise will apply for, thus improving the innovation performance. The research of Du and Guo (2021) shows that R&D investment determines the development of enterprises to some extent. They develop new products, standardize the management of the achievements of innovation, and improve the market adaptability of the achievements of innovation. Wang (2018) concluded that increasing R&D investment can improve the ability of enterprises to make technological breakthroughs and produce more innovative products to help enterprises win in the market competition.

In summary, from many literatures written by domestic and foreign scholars, the influence of R&D input on innovation performance is discussed in different ways. After statistics and research on enterprise data, they believe that increasing R&D input can improve the existing technical strength, promote the adjustment and transformation of industry and industrial chain, and improve innovation performance. According to the above discussion, innovation openness has a significant positive effect on R&D input, and R&D input has a significant positive effect on enterprise innovation performance, and R&D input can become an effective factor for innovation openness to improve innovation performance.

Therefore, the following hypothesis is obtained:

H3: R&D investment has a significant positive impact on innovation performance.

H4: R&D investment plays a mediating role between innovation openness and innovation performance.

2.4 Moderating Effect of Innovation Efficiency

Koopmans (1951) et al. proposed innovation efficiency in 1951. In 1957, Farrel proposed that the maximum output under a certain input or the minimum consumption under a maximum output could be called technical efficiency (Farrel, 1957). In the whole process of innovation, the ultimate goal is to transform the minimum R&D investment into the maximum economic output. Enterprises with high innovation efficiency have strong competitiveness in the market, which can often save

costs for enterprises, reduce the time spent in each link, accelerate the speed from technology research and development to product research and development to the transformation of results, and play a key role in the improvement of innovation performance.

After a careful study of the existing literature, it is found that there are more studies on the effect of innovation efficiency on enterprise performance, but few studies on the impact of innovation efficiency on innovation performance. For example, Gu (2012) applied DEA method, took high-tech industry as the research object, and found that the business performance of enterprises would increase with the improvement of innovation efficiency. The research results of Hu and Ji (2017), Dai and Zheng (2018) also show that the improvement of innovation efficiency will promote enterprise performance. Zeng et al. (2020), by studying strategic enterprises and taking listed enterprises in emerging industries as the main analysis objects, found that the improvement of innovation efficiency would promote enterprise performance. In order to cope with the changes in complex market environments and improve the speed of technology and product updates, enterprises need to improve the efficiency of innovation under the condition of a certain amount of R&D investment. Otherwise, the original technological advantages of enterprises will become no longer important, and enterprises will soon be surpassed or even replaced. With different innovation efficiency, the effect of R&D input on higher innovation performance is also different. Higher innovation efficiency, stronger role of R&D investment, and more improvement of innovation performance; However, when enterprises are in the situation of low innovation efficiency, R&D input cannot be fully utilized, the effect of R&D input becomes weak, and its influence on innovation performance becomes low.

Therefore, the following hypothesis is obtained:

H5: Innovation efficiency plays a moderating role between R&D input and innovation performance.

Based on the above analysis, innovation openness can affect innovation performance by influencing R&D input, and the change in innovation efficiency also affects the relationship between R&D input and innovation performance. Therefore, it is concluded that the higher the innovation efficiency, the better the impact on innovation performance under the condition of a certain amount of R&D investment.

Therefore, the following hypothesis is obtained:

H6: Innovation efficiency positively moderates the mediating role of R&D investment in innovation openness and innovation performance.

Therefore, the theoretical model of this paper is shown in Fig. 1.

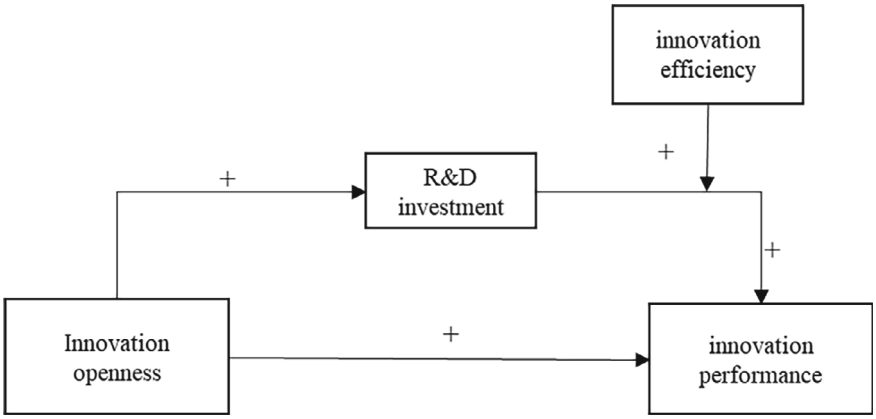

Fig. 1 Theoretical model

3 Research Design

3.1 Sample Selection and Data Sources

In this paper, 2,768 listed companies of Shanghai and Shenzhen A-share manufacturing industry are selected as the research objects, and 2011–2021 is selected as the research period, with A total of 16,974 data pieces. The sample data is mainly collected from Guotai's database and China research Data Service platform. In addition, based on the experience of most scholars, the samples were screened according to the following requirements: (1) ST or *ST enterprises were excluded. (2) Delete the enterprise whose key data is missing. (3) Because this paper is based on patent data, enterprises with a total of 0 patent applications and enterprises with a total of 0 invention patents are excluded. (4) In order to avoid the influence of values deviating from the data subject in the sample data on the results, the tail reduction of related variables was carried out.

3.2 Variable Selection

3.2.1 Explained Variable

Innovation performance (IP): According to existing studies, this paper uses the number of patent applications to measure the innovation performance of enterprises. Compared with the time of patent application, the time of patent authorization is affected by many external factors (Degener et al., 2018), so this paper chooses the time of patent application. In addition, invention patents are the most difficult in

the process of R&D, which helps to measure innovation performance (Leeuw et al., 2019). Therefore, this paper measures innovation performance mainly through the number of invention patent applications.

3.2.2 Explanatory Variable

Innovation openness (OPEN): Based on the practice of Wang et al. (2015) and other scholars, this paper measures innovation openness by the ratio of the number of cooperative patent applications and the total number of patent applications.

Descriptive statistical results show that the minimum openness is 0, the maximum is 1, the mean is 0.107, and the standard deviation is 0.219, indicating that domestic manufacturing enterprises ignore the importance of openness, therefore, in order to better distinguish enterprises, with reference to the practice of Wang Jian et al., when the openness is 0, the value of OPEN is 0; when the openness is greater than 0, the value of OPEN is 1.

3.2.3 Mediating Variable

R&D investment (RD): R&D investment is one of the important decisions in the strategic deployment of enterprises. If the R&D investment is set reasonably, the ideal effect will be achieved, which can enhance the innovation ability of enterprises, develop more innovative products and help enterprises to obtain profits and innovation competitiveness. Therefore, this paper adopts the measurement method of R&D input proposed by Wang and Ai (2018), which is directly represented by the natural logarithm of R&D input.

3.2.4 Mediating Variable

Innovation efficiency (IE): Innovation efficiency refers to the proportion of R&D achievements in innovation resource investment, which indicates how many units of patents can be brought by each unit of R&D investment and labor force. The higher the innovation efficiency, the better the development of the enterprise. According to the method of Quan and Yin (xxxx), the number of invention patent applications per unit of R&D input is used to measure the innovation efficiency of enterprises.

3.2.5 Control Variable

At the enterprise level, the following variables are selected as major constraints in this study. ① Control the Size of the enterprise (Size), and use the natural logarithm of the total asset size of the enterprise to measure. ② The asset-liability ratio (Lev) is controlled and measured by the ratio of total liabilities to total assets in the current

year. ③ Control of ownership concentration (CR1), choose the largest shareholder shareholding ratio to express. ④ Control the Year.

3.3 Model Design

The results of Hausman test indicate that fixed effect model should be used for analysis. In order to verify the effect of innovation openness on innovation performance, the following model is designed to test the relationship among variables, where Control represents all control variables.

$$\mathrm{IP} = \beta_0 + \beta_1 \mathrm{OPEN} + \beta_2 \mathrm{Control} + \varepsilon \tag{1}$$

Model (1) includes innovation performance IP, innovation openness OPEN and Control variable, which is mainly used to test the main effect, namely the effect of innovation openness and innovation performance. According to the research hypothesis H1, the preset coefficient β_1 is positive.

$$\mathrm{RD} = \beta_0 + \beta_1 \mathrm{OPEN} + \beta_2 \mathrm{Control} + \varepsilon \tag{2}$$

$$\mathrm{IP} = \gamma_0 + \gamma_1 \mathrm{OPEN} + \gamma_2 \mathrm{RD} + \gamma_3 \mathrm{Control} + \varepsilon \tag{3}$$

The model (2) contains the intermediate variable RD, the explanatory variable OPEN and the control variable, and is mainly used to test the effect of innovation openness on R&D input. According to hypothesis H2, the preset coefficient β_1 is positive; Model (3) includes innovation performance IP, innovation openness OPEN, R&D input RD and control variables. It is mainly combined with model (2) and model (1) to test the effect of innovation openness on innovation performance by influencing R&D input RD, that is, to verify hypothesis H4. The preset coefficients $\gamma 1$ and γ_2 are positive, and the coefficient γ_1 is smaller than the coefficient β_1.

$$\mathrm{IP} = \beta_0 + \beta_1 \mathrm{RD} + \beta_2 \mathrm{Control} + \varepsilon \tag{4}$$

$$\mathrm{IP} = \gamma_0 + \gamma_1 \mathrm{RD} + \gamma_2 \mathrm{IE} + \gamma_3 \mathrm{Control} + \varepsilon \tag{5}$$

$$\mathrm{IP} = \delta_0 + \delta_1 \mathrm{RD} + \delta_2 \mathrm{IE} + \delta_3 \mathrm{RD} \times \mathrm{IE} + \delta_4 \mathrm{Control} + \varepsilon \tag{6}$$

Model (4) is divided into three parts to test the impact of changes in innovation efficiency on R&D input and innovation performance. Model (4) is used to test the relationship between R&D investment and innovation performance. According to hypothesis H3, β_1 is assumed to be positive. In Model (5), innovation efficiency is added on the basis of model (4) to test the relationship among R&D input, innovation

efficiency and innovation performance. Based on Model (4), the interaction term between R&D input and innovation efficiency is added to Model (5) to test the moderating effect of innovation efficiency. According to hypothesis H5, the preset coefficient δ_3 is positive.

4 Analysis of Empirical Results

4.1 Descriptive Statistics of Variables and Correlation Analysis

In this paper, STATA15.0 statistical analysis software was used to organize the sample data. Table 1 shows the correlation between variables and the descriptive statistical results. Descriptive statistics show the mean and standard deviation of the main variables in this paper. The results of correlation analysis showed that innovation openness had a positive effect on innovation performance ($r = 0.260$, $p < 0.01$) and R&D investment ($r = 0.336$, $p < 0.01$); R&d investment positively affected innovation performance (r = 0.535, p < 0.01); Innovation efficiency positively affected innovation performance ($r = 0.667$, $p < 0.01$). To sum up, it indicates that the variables selected in this paper are correlated. In addition, VIF is used to test multicollinearity in this study. The results show that VIF values of all variables are less than 5, indicating that there is no phenomenon that one explanatory variable can be linearly represented by other explanatory variables. The variables selected in this paper are set appropriately and can be studied and analyzed in the next step.

Table 1 Descriptive statistics of variables and correlation coefficients

	1	2	3	4	5	6	7
IP	1.000						
OPEN	0.260***	1.000					
RD	0.535***	0.336***	1.000				
IE	0.667***	0.365***	0.512***	1.000			
Size	0.502***	0.345***	0.749***	0.450***	1.000		
Lev	0.234***	0.164***	0.347***	0.241***	0.524***	1.000	
CR1	0.040***	−0.013*	0.058***	0.020***	0.094***	−0.002	1.000
Mean value	31.84	0.847	18.14	0.139	22.08	0.385	33.61
Standard deviation	70.39	0.360	1.306	0.0612	1.158	0.189	14.04

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

4.2 Hypothesis Testing

4.2.1 Test of Main Effect and Intermediate Effect

Table 2 shows the test results of the main effect and intermediate effect. Models 1 to 2 are used to test the impact of innovation openness on R&D investment. Models 3 to 5 are used to test the impact of innovation openness on R&D input and innovation performance.

Model 3 is a basic model that only includes control variables, and Model 4 is formed after innovation openness is added. According to model 4, the coefficient of innovation openness of independent variable is 6.404 ($p < 0.01$), indicating that innovation openness has a positive impact on innovation performance. Therefore, hypothesis H1 is confirmed.

Model 1 is the basic model including only control variables, and Model 2 is formed after adding innovation openness. Model 2 shows that the coefficient of innovation openness is 0.034 ($p < 0.01$), which indicates that R&D investment increases by 0.034 units for each unit increase in innovation openness. So let's say H2 is confirmed.

Model 5 shows that the influence coefficient of R&D input on innovation performance is 6.533 ($p < 0.01$), which is a positive correlation, indicating that the increase in R&D investment leads to the improvement of innovation performance. So, hypothesis H3 is confirmed. After both explanatory variables and mediating variables were added to the model, innovation openness was still linearly correlated with innovation performance, with a coefficient of 6.185 ($p < 0.01$), which is less than the coefficient of 6.404, indicating that the change of innovation openness will lead to the change of R&D input and improve innovation performance. So, hypothesis H4 is confirmed.

Among them, the R^2 of models 3–5 is relatively low because some control variables are not covered or there are some problems in the form of the model.

4.2.2 Adjustment Effect Test

Table 3 shows the results of the moderating effect, which is used to test the moderating effect of innovation efficiency on R&D input and innovation performance. In order to get more accurate and scientific results, the two variables of R&D investment and innovation efficiency are treated centrally. Model 6 is a model containing only control variables. Model 7 is formed by adding R&D investment on the basis of Model 6. According to model 7, innovation performance increases by 6.695 units for every unit increase in R&D input, indicating that R&D input will have a positive impact on innovation performance. Hypothesis H3 is further confirmed.

Model 8 shows that the coefficient of innovation efficiency is 443.433 ($p < 0.01$), innovation efficiency has a positive effect on innovation performance. Model 9 is a variable with the interaction between R&D input and innovation efficiency added into Model 8. The results show that the coefficient of interaction term is 290.289 ($p < 0.01$), indicating that the interaction between R&D input and innovation efficiency has a

Table 2 Main effect test and intermediate effect test

Variable	RD		IP		
	Model 1	Model 2	Model 3	Model 4	Model 5
Independent variable					
OPEN		0.034*** (0.011)		6.404*** (0.842)	6.185***
Mediating variable					
RD					6.533*** (1.305)
Control variable					
Size	0.820*** (0.027)	0.816*** (0.027)	23.715*** (2.895)	22.943*** (2.844)	17.611*** (2.603)
Lev	−0.313***	−0.312*** (0.075)	−26.075*** (6.641)	−25.774*** (6.608)	−23.738*** (6.465)
CR1	0.001 (0.001)	0.001 (0.001)	0.178 (0.134)	0.182 (0.134)	0.173 (0.132)
Year	Control	Control	Control	Control	Control
N	16,974	16,974	16,974	16,974	16,974
R^2	0.602	0.603	0.119	0.123	0.129

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 3 Test of adjustment effect

Variable	IP			
	Model 6	Model 7	Model 8	Model 9
Mediating variable				
RD		6.695*** (1.316)	5.895*** (1.166)	4.345*** (1.247)
Regulating variable				
IE			443.433*** (18.927)	474.439*** (16.150)
Interaction term				
RD x IE				290.289*** (18.182)
Control variable				
Size	23.715*** (2.895)	18.223*** (2.644)	8.758*** (2.163)	3.502** (1.763)
Lev	−26.075*** (6.641)	−23.977*** (6.494)	−23.554*** (5.546)	−12.631*** (3.701)
CR1	0.178 (0.134)	0.169 (0.132)	0.115 (0.114)	0.030 (0.082)
Year	Control	Control	Control	Control
N	16,974	16,974	16,974	16,974
R^2	0.119	0.125	0.314	0.539

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

positive impact on innovation performance, and innovation efficiency plays a positive moderating role between R&D input and innovation performance. Hypothesis H5 is confirmed.

In order to take into account the moderating effect of innovation efficiency, a simple slope test is conducted, and the results are shown in Fig. 2. As can be seen from Fig. 2, the real line slope of high innovation efficiency is higher than that of low innovation efficiency, indicating that with the improvement of innovation efficiency, R&D input has a deeper positive impact on innovation performance. It is shown that innovation efficiency plays a moderating role between innovation openness and R&D investment. Hypothesis H5 is further verified.

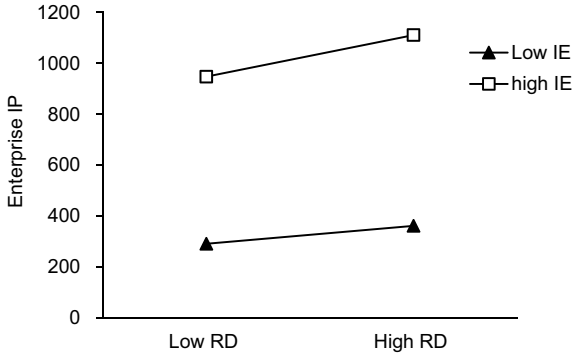

Fig. 2 Moderating effect of innovation efficiency