R&D Investment, Innovation Output and Enterprise Competitiveness: A Perspective of Employee Education

Liangcheng Wang, Shengkun Wang, Tao Peng*

Business School of Sichuan University, Chengdu 610000, China

*Corresponding author. Tel.: +86 13060023687.

Email addresses: wangle@scu.edu.cn (L.Wang), 1179712019@qq.com (S.Wang), ptao1217@163.com (T.Peng).

Abstract: The study examines whether employee education plays a role in firm’s competitiveness, particularly in innovation activities. The innovation activity has two paths: technologic output and the transformation of scientific achievements. Using the sample of 174 listed companies of top 500 companies in china, we find that innovation output and enterprise competence have significant “inverted U” relationship; constrained by efficiency in achievement transformation path, R&D investment has significant negative effect on enterprise competence. Innovation output plays a completely mediating role in the relation between R&D investment and enterprise competence. Employee education has negative regulating effect on the first path, but the study has not found significant regulating effect on achievement transformation path.

1. Introduction

In the current era of globalization with increasing competition and uncertainty, how to improve independent innovative ability to improve competitiveness is a great challenge for firms specially in the emerging markets. While a large body of literatures has investigated the innovative activities as a whole, there is little attention paid to the mediating role of technical innovation output and regulating role of employee education in firm’s innovative activities.

The firm first creates new technologies through R&D investment, and produce the final economic results through commercialization of technology to enhance the competitiveness of the company. In addition, knowledge and ability of employees also have a significant impact on all stages of enterprise innovation activities. Highly educated employees can better access external knowledge and make full use of existing resources to achieve innovation (Wang and Jiang, 2020).

While a large body of literatures has investigated the high-tech enterprises, there is little attention paid to China's top 500 enterprises. However, the top 500 companies contribute to China's economy, globalization implementation and international competitiveness of Chinese enterprises. Research on top 500 companies can develop their advantage to improve competitiveness and provide advanced experience in future management.

Therefore, this study focuses on the innovative activities of China's top 500 enterprises, and explores the mediating role of technological innovation output and the role of employee education in regulating separately. The contributions are as following: First, we use the competitiveness index of the top 500 companies to avoid the unreliable research results. Second, this article introduces innovation output as
intermediary variables in innovation activities. The innovation activity has two paths: technologic output and the transformation of scientific achievements. Third, this article will use employee education as the proxy variable for employees' comprehensive knowledge and ability to explore the regulating effect of employee education on the two processes of innovation activities.

2. Research hypothesis

2.1. R&D investment and technological innovation output
A large body of literatures has investigated that R&D expenditure contributes to the number of patents (e.g. Pakes and Griliches, 1980; Li and Liu, 2017; Yang et al., 2018) and has a lag of 1-3 period (Shang and Huang, 2018).

Generally, enterprises with greater the intensity of R&D investment will have more abundant resources to innovate, therefore they will be more conducive to achieve technological innovation breakthrough, and the enterprise's technological innovation output will correspondingly increase. Based on the above analysis, the following hypothesis is proposed:

H1: The R&D investment of enterprises has a significant positive impact on the output of technological innovation, and there is a certain lag.

2.2. Technological innovation output and enterprise competitiveness
A large body of literatures has investigated that innovation output has a significant positive effect on their competitiveness (e.g. Zhu and Yang, 2019; Lei and Wang, 2014). Some scholars hold different views. Technological innovation output does not play a significant role in improving the enterprise competitiveness (Li and Liu, 2017) or profit margin (Wang Yimin, 2012), especially in domestic enterprises (Le Qi et al. 2008).

Although enterprise with higher level of technological innovation output will have more resources to create value for customers, a small amount of innovation output may not improve enterprise competitiveness. The process of turning innovative output into enterprise competitiveness is full of uncertainty, which needs financial and human capital to carry out secondary innovation. Therefore, based on the above analysis, this paper presents the following hypothesis:

H2: The output of technological innovation has a nonlinear effect on the enterprise competitiveness, and the influence of technological innovation output on enterprise competitiveness has threshold effect and lag.

2.3. R&D investment and enterprise competitiveness
Rich empirical research shows that R&D investment is significantly positively correlated with the enterprise competitiveness within a certain range (Aguja and Katina, 2001; Barker and Mueller, 2002; Pang et al., 2014; Wu, 2015; Zhu, 2019; Li, 2014). Some scholars hold other views. The innovation input of enterprises has a negative impact on the market competitiveness (Zhou Dan, 2014), the profit margin (Wang, 2012) and shareholder returns (Mank and Nystrom, 2001). The business risk of good economic performance is relatively small. Therefore, such enterprises probably prefer to maintain the status quo and more conservative in the intensity of R&D investment (Hitt et al., 1991).

R&D investment can effectively promote enterprise competitiveness is restricted by the ability of enterprise patent conversion. However, the accumulation of long-term R&D can bring irreplaceable innovation output, so as to help enterprises obtain new patents, create new products, occupy new markets, bring excess revenue and continuous competitive advantages, and keep a leading position in the fierce competition. Based on the above analysis, the following hypothesis are proposed:

H3: The R&D investment of enterprises has a significant positive impact on the enterprise competitiveness, and there is a lag.

2.4. The mediating effect of technology innovation output
The technological innovation process has two processes: science and technology system and economic system. The number of patents and R&D projects is not only the output of science and technology system, but also the input of economic system (Li, 2019; Wang, 2019; Fortune and Shelton, 2012; Le, 2008).

As some scholars mentioned, the process of enterprise innovation activities can be summed up as: the formation of new thinking - R&D investments - the generation of new technologies - the commercialization of technology - the output of economic results (Li, 2017). Technological innovation output is the intermediate output, which is the link between R&D investment and enterprise competitiveness. Based on the above analysis, this paper presents the hypothesis:

H4: Technological innovation output plays a mediating role in the relationship between R&D investment and enterprise competitiveness.

2.5. The adjustment effect of employee's education

A large body of literature has investigated that employee education has a positive effect on the output of technological innovation by improving the ability of patent output (Xiao and Zhu, 2015; Wang and Jiang, 2020; James, 2002; Wang and Wang, 2016). Moreover, highly educated employees are most likely to apply new knowledge and challenge the existing knowledge and norms, so as to transform the existing knowledge into a diversified field of knowledge and make transformation and innovation of products and services (Technological Discontinuities and Organizational Environments, 1986).

The speed and success rate of transforming innovation output depend on knowledge and competence of R&D personnel. The effective transformation of technological innovation output into higher customer value depends on the ability of employees to convert into products or services that customers need. The improvement of the educational structure of employees is beneficial to the smooth progress of all stages of enterprise innovation activities. Based on the above analysis, the following hypotheses are proposed:

H5a: Employee education has a regulating effect on the relationship between R&D investment and technological innovation output.

H5b: Employee education has a regulating effect on the relationship between technological innovation output and enterprise competitiveness.

2.6. Research model

![Research model](image)

3. Research design

3.1. Variable definition and indicator selection

There is no unified measure of enterprise competitiveness. If selecting some financial indicators as a measure, it is probably not convincing. Therefore, this paper adopts the 2018 China Top 500 Enterprise Competitiveness Index issued by Shanghai University of Finance and Economics as a measure. The calculation finished by experts in Shanghai University of Finance and Economics can measure enterprise competitiveness evaluated objectively and fairly.

This paper selects the absolute value of R&D investment to measure the intensity of R&D investment. Due to the great difference in different industries, this paper selects the relative value of the number of patent applications (patent applications/average patent applications in the industry) to measure the level of innovation output of enterprises.
### Table 1 Variable interpretation

| Variable | Description |
|----------|-------------|
| EC       | The Competitiveness Index of Shanghai University of Finance and Economics |
| RD       | The average R&D investment |
| IO       | actual number of patent applications /industry average of the number of patent applications |
| EDU      | the proportion of the enterprise's undergraduate education level to the total of employees |
| Cash     | the ratio of cash flow from operating activities to total assets in 2018 |
| TobinQ   | the 2018 Corporate Tobin Q value, equal to the company's market value replacement cost |
| PE       | the 2018 corporate price-earnings ratio, equal to the stock price/earnings per share |
| ESR      | the proportion of corporate executive shareholdings in 2018, equal to the sum of the total number of shares held by enterprise executives/total shares of the enterprise |
| TAGR     | the growth of total assets at the end of 2018 to the total assets at the beginning of the year |
| NPGR     | the increase in net profit of enterprises in 2018 to the net profit of the previous period |
| TATR     | the ratio of net sales revenue to average total assets in 2018 |
| Second   | Virtual variables, the chairman and general manager concurrently =1, non-concurrently =0. |
| PR       | Virtual variables, state-owned = 1; non-state-owned = 0 |
| Year     | Year of report-year of establishment |

#### 3.2. Sample selection and data sources

This study selected the A-share listed companies in the top 500 enterprises in the Financial Competitiveness Index, while excluding the enterprises that were not listed, listed by subsidiaries and the enterprises that could not obtain the employee education. The competitiveness data is derived from the 2018 "Shanghai University of Finance and Economics 500 Competitiveness Index", employee education data from the Wind database, the rest of the data from the CSMAR database.

#### 3.3. Model

##### 3.3.1. Main effect test

\[
EC = a_0 + a_1RD + a_2CL + e_1 \quad (1)
\]
\[
IO = b_0 + b_1RD + b_2CL + e_2 \quad (2)
\]
\[
EC = c_0 + c_1IO + c_2IOIO + c_3CL + e_3 \quad (3)
\]

The judgment of the relationship between the investment of R&D, the output of technological innovation and the enterprise competitiveness is the main effect test of this paper.

##### 3.3.2. Mediating effect test

\[
EC = d_0 + d_1IO + d_2IOIO + d_3RD + d_4CL + e_4 \quad (4)
\]

Refer to Bardon's three-step method of the mediating effect test (Bardon and Kenny, 1986): The first and second steps of the mediating effect test have been completed by the equation (1) and (2), and the third step is done by the equation (4).

##### 3.3.3. Regulating effect test

According to the study of the mediating model of moderation (Wen and Ye, 2014), the mediating effect test is carried out in three steps:

\[
EC = a_0 + \alpha_1RD + \alpha_2EDU + \alpha_3RD \times EDU + \alpha_4CL + e_1 \quad (5)
\]
\[
IO = \beta_0 + \beta_1RD + \beta_2EDU + \beta_3RD \times EDU + \beta_4CL + e_2 \quad (6)
\]
\[
EC = \gamma_0 + \gamma_1RD + \gamma_2IO + \gamma_3EDU + \gamma_4M \times EDU + \gamma_5CL + e_3 \quad (7)
\]

If the result of equation (6) is not significant, indicating that the employee's education does not play a regulating role in the first path, then M only represents the enterprise technology innovation output, the interaction variables are \( EDU \times IO \) , \( EDU \times IOIO \); If the result of equation (6) is significant,
indicating that the employee's education plays a regulating role in the first path, then M represents the enterprise R&D investment and technology innovation output, the interaction variables are $EDU \times RD$ and $EDU \times IO \times IO$.

4. Empirical results

4.1. Descriptive statistics and correlation analysis

The enterprise competitiveness scores vary from 7.411 to 192.831, with an average score of 95.656, indicating that the competitiveness levels varied widely. The average proportion of undergraduate employees in enterprises is about 30%, varying from 87.8% to 0.25%, indicating significant differences in the educational level of enterprise employees.

| Variables | Observations | Mean  | Std.Dev | Min  | Max   |
|-----------|--------------|-------|---------|------|-------|
| EC        | 174          | 95.659| 39.492  | 7.411| 192.831|
| RD        | 174          | 6.28e+08| 1.58e+09| 0    | 1.00e+10|
| EDU       | 174          | 29.432| 19.595  | .25  | 87.823|
| IO        | 174          | 1     | 2.833   | 0    | 30.501|
| PR        | 174          | .517  | .501    | 0    | 1     |
| second    | 174          | .178  | .384    | 0    | 1     |
| year      | 174          | 21.879| 5.915   | 7    | 39    |
| cash      | 174          | .052  | .074    | -.159| .371  |
| ESR       | 174          | .008  | .03     | 0    | .257  |
| PE        | 174          | 26.307| 76.548  | -78.591| 794.197|
| TobinQ    | 174          | 1.208 | .554    | .711 | 4.902 |
| TAGR      | 174          | .107  | .165    | -.227| .917  |
| NPGR      | 174          | -.429 | 8.488   | -109.076| 15.211|
| TATR      | 174          | .941  | 1.156   | .023 | 9.663 |

4.2. Regression results

4.2.1. Main effect test

In Table 3, the equation (3) and (4) are designed to test the effect of the enterprise's R&D investment on the output of technological innovation. Equation (4) include only control variables for comparison. The results show that the investment in R&D has a significant positive impact on the output of technological innovation. Therefore, hypothesis H1 is correct.

The equation (5) and (6) in Table 3 are designed to test the nonlinear relationship between technological innovation output and enterprise competitiveness. The results show that the enterprise competitiveness innovation output has a non-linear positive U-type influence on enterprise. Therefore, hypothesis H2 is correct. From further calculation, we can find that and enterprise competitiveness showed a positive "U"-type relationship with the threshold 16.0136, and 99% of the samples in the study did not reach the threshold. Although t R&D investment are gradually increasing, enterprises easily ignore the process of commercialization of technological innovation output. Only when the innovation output of enterprises reaches a certain scale, even if a certain proportion of innovation output is not effectively converted into economic benefits, the number of effective transformations is still considerable, so that it can positively affect the enterprise competitiveness. A small amount of technological innovation may make little improvement for enterprise products, and may not be able to make up for the input and thus cannot effectively enhance the enterprise competitiveness.

Table 3 equation (1), (2) test the impact of R&D investment on the enterprise competitiveness. The results show that the R&D investment has a significant negative impact on the enterprise competitiveness. Therefore, hypothesis H3 is not correct. As mentioned above, 99% of the enterprise
innovation output in this sample does not reach the threshold of positive impact on the enterprise competitiveness, the efficiency is still low, so the R&D investment shows a certain inhibition effect on the enterprise competitiveness, which is consistent with Fortune and Shelton (2002).

Table 3 Results of R&D investments, technological innovation outputs and enterprise competitiveness

| VARIABLES | (1) | (2) | (3) | (4) | (5) | (6) |
|-----------|-----|-----|-----|-----|-----|-----|
| RD        | 6.09e-09** | 7.25e-10*** |       |       |     |     |
|           | (2.49e-09) | (1.36e-10) |       |       |     |     |
| IO        | -8.263*** |       |       | 0.258** |       |     |
|           | (3.153) |       |       | (0.124) |       |     |
| Controls  | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant  | 90.36*** | 76.50*** | -0.295 | 1.357 | 82.61*** | 76.50*** |
|           | (20.23) | (19.72) | (1.104) | (1.146) | (19.54) | (19.72) |
| Observations | 174 | 174 | 174 | 174 | 174 | 174 |
| R-squared | 0.092 | 0.059 | 0.174 | 0.028 | 0.100 | 0.059 |

(Note: *, **, *** represent the significance levels of 10%, 5%, and 1%, )

4.2.2. Mediating effect test

The first two steps of the mediating effect test are completed by equations (1) and equations (3) in Table 3, and the third step is done by equation (1) in Table 4. By taking the enterprise innovation output and enterprise R&D investment as the argument and enterprise competitiveness as dependent, it is found that the influence of enterprise R&D investment on enterprise competitiveness is no longer significant, and the enterprise innovation output still has a significant positive U-type influence on the enterprise competitiveness. Therefore, hypothesis H4 is correct.

Table 4 The regression results of the mediating effect test of technological innovation output

| VARIABLES | (1) | (2) |
|-----------|-----|-----|
| IOIO      | 0.215* |       |
|           | (0.127) |       |
| IO        | -6.412* |       |
|           | (3.376) |       |
| RD        | -4.13e-09 |       |
|           | (2.76e-09) |       |
| Controls  | Yes | Yes |
| Constant  | 90.35*** | 76.50*** |
|           | (20.14) | (19.72) |
| Observations | 174 | 174 |
| R-squared | 0.113 | 0.059 |

4.2.3. Regulating effect test

Equations (1) and (2) in Table 5 are designed to test the regulating effect of employee education for the relationship between R&D investment and enterprise competitiveness. There is no significant regulating effect of employee education for the relationship between R&D investment and enterprise competitiveness.

Equations (3) and (4) in Table 5 are intended to test whether the employee education has regulating effect in the first path. The results show that employee's education has a significant negative regulating effect in the relationship between the enterprise's R&D investment and enterprise technology innovation.
output, which supports H5a. This is consistent with Wu and Lou (2019). There is a negative adjustment effect on the investment of R&D and the enterprise technological innovation output, and the employee education in Equation (1) has a negative influence on the enterprise competitiveness, consistent with the results of other scholars (Le Qi et al, 2008). This result deserves attention. Enterprise's increase in highly educated R&D personnel may increase the R&D investment, but the new highly educated R&D personnel may not significantly increase the number of patents in the short term, so the employee education presents a negative regulating role.

Since employee education has a significant regulating effect, the interaction terms should be IO×EDU, IOIO×EDU and RD×EDU in the second path. In equation (5) of Table 5, results show that there is no regulating effect of employee education between technology innovation output and enterprise competitiveness, which does not support H5b. However, there are enterprises whose overall education level is not highly but has excellent R&D team, such as manufacturing enterprises. In addition, the recruitment of highly educated employees will result in higher labor costs, but the economic benefits brought by highly educated employees for enterprises may not be reflected in a timely and effective manner. Actual lag period may be longer than assumed.

| VARIABLES | (1) | (2) | (3) | (4) | (5) | (6) |
|-----------|-----|-----|-----|-----|-----|-----|
| RD        | 7.85e-09 | 2.23e-09*** | 2.31e-09 | (4.77e-09) | (3.57e-10) | (5.44e-09) |
| IO        | 8.339 | 0.906*** | 0.0139 | (0.160) | (0.0120) | (0.182) |
| IOIO      | -0.502 | -0.214 | 0.956*** | (0.397) | (0.196) | (0.0195) |
| EDU       | 0.906*** | 0.0139 | 0.956*** | (0.160) | (0.0120) | (0.182) |
| IOEDU     | -0.214 | 0.0216 | 0.0195 | (0.196) | (0.0195) | |
| IOIOEDU   | -3.47e-11 | -3.57e-11*** | 6.54e-11 | (1.06e-10) | (7.90e-12) | (1.17e-10) |
| RDEDU     | -3.47e-11 | -3.57e-11*** | 6.54e-11 | (1.06e-10) | (7.90e-12) | (1.17e-10) |
| Controls  | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant  | 53.60*** | 94.95*** | -1.052 | 1.357 | 53.14*** | 94.95*** |
| Observations | 174 | 174 | 174 | 174 | 174 | 174 |
| R-squared | 0.327 | 0.086 | 0.269 | 0.028 | 0.348 | 0.086 |

### 4.3. Robustness test
This paper takes two ways to test the robustness. First, change the R&D investment into the use of R&D manpower input (number of enterprise technicians). Second, select enterprises with innovation output before the threshold as a research sample to observe whether the technological innovation output shows a linear negative influence on the competitiveness of the enterprise. The results of the robustness test are fully in line with the empirical results of the previous results.

### 5. Conclusions
First, the intensity of enterprise R&D investment has a significant positive impact on the level of innovation output, which has a certain lag.

Second, the technological innovation output has a significant positive U-type influence on enterprise competitiveness with threshold effect and lag. Only when the patent application of an enterprise reaches
a certain number can the innovation output of the enterprise effectively promote the enterprise competitiveness.

Third, R&D investment has a significant negative impact on the enterprise competitiveness, which has a certain lag. The influence is restricted by the process of commercialization of technological innovation output.

Fourth, technological innovation output plays an regulating role in the relationship between the investment of R&D and the enterprise competitiveness.

Fifth, the employee education plays a negative role in the first path of innovation activities, while the relationship between innovation output and enterprise competitiveness is not moderated.

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References
[1] Del A. Mank, Halvard E. Nystrom. Decreasing Returns to Shareholders From R&D Spending in the Computer Industry[J]. Engineering Management Journal, 2001, 13(3).
[2] Duan Xuan. Research on enterprise R&D investment, technological innovation and resource input utility [J]. Statistics and Decision, 2020, 36 (01): 181-184.
[3] Fortune, A. & Shelton, L. R&D Effort, Effectiveness and Firm Performance in the Pharmaceutical Sector [J]. Journal of Business and Management, 2012, 18(1):97-115.
[4] Gautam Ahuja, Riitta Katila. Technological acquisitions and the innovation performance of acquiring firms: a longitudinal study[J]. Strategic Management Journal, 2001, 22(3).
[5] Li Honglian. A Study on the Efficiency of Agricultural Technology Innovation in the Central Region [D]. Huazhong Agricultural University, 2017.
[6] Li Yanlin, Cheng Jun, Li Qiang. R&D investment, achievement transformation and enterprise competitiveness [J]. Friends of Accounting, 2014 (09): 54-58.
[7] Li Zuozhi, Su Jingqin, Liu Xiaoyan. Study on the efficiency of technological innovation in China's high-tech industry [J]. Science and Technology Management, 2019, 40 (12): 31-41.
[8] Pakes A, Griliches Z. Patents and R and D at the Firm Level: A First Look[J]. Economics letters, 1980, 5(4):377-381.
[9] Shang Hongtiao, Huang Xiaoqiong. Dynamic interaction effects of government subsidies, R&D investment and innovation performance [J]. Science Research, 2018, 36 (03): 446-455 + 501.
[10] Tam, C.D., Gielen, ETP. Technology Learning and Deployment in Support of the G8 Plan of Action[Z]Paris: International Energy Agency, 2008.
[11] The Battle of Innovation [M]. Machinery Industry Press, (Germany) by Christoph-Friedrich von Braun, 1999.
[12] Wang Juan, Wang Yi. Education level of enterprise employees and enterprise innovation performance [J] Journal of Xi’an Jiaotong University, 2016, 36 (06): 40-46.
[13] Wang Zongjun, Jiang Zhenyu. From knowledge acquisition to innovation ability: the regulatory effect of information literacy [J]. Science Research Management, 2020, 41 (01): 274-284.
[14] Wen Zhonglin, Ye Baojuan. Regulated intermediary model test method: competition or replacement? [J]. Psychological Journal, 2014, 46 (05): 714-726.
[15] William M. James. The Human Side: Best HR Practices for Today's Innovation Management[J]. Research-Technology Management, 2002, 45(1).
[16] Wu Zhenni, Lou Shiyan. The interaction of education and employee duality on organizational non-financial performance [J]. Chongqing Social Sciences, 2019 (04): 104-117.