An Empirical Study on the Impact of R&D Investment on Firm Performance based on Total Factor Productivity Mediation Effect

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Abstract. Using the data of GEM listed companies from 2012-2019 as the research sample, this paper explores the impact of R&D investment on firm performance in terms of the mechanism by which R&D innovation investment affects the internal productivity of firms and then transmits to firm performance, and determines whether the internal productivity of firms plays a mediating role in promoting the relationship between firm innovation and firm performance. It is found that R&D investment can effectively improve firm performance, and total factor productivity plays an incomplete mediating role between the two, i.e., the improved effect of R&D investment on firm performance is partly achieved by increasing total factor productivity.

Keywords: R&D Investment; Enterprise Performance; Total Factor Productivity; Mediation Effect.

1. Introduction

In recent years, the innovation-driven development strategy has become a major strategic decision to achieve socialist modernization in China, and research and innovation has become an important way for enterprises to gain core competitiveness and improve financial performance. Studying the relationship between R&D investment and enterprise performance helps to better help enterprises optimize resource allocation, improve R&D efficiency, bring into play the role of capital market, form a virtuous cycle, and promote technological innovation and technological progress in China.

2. Literature Review

Scholars at home and abroad have found an important relationship between innovative R&D and enterprise development at an early stage, and a large number of scholars believe that there is a significant positive relationship between R&D investment and enterprise performance. Chen(2013) argued that the correlation coefficient between R&D investment intensity and financial performance indicators has a large variability among different industries [1]; Du et al. (2014) proved that R&D investment of high-tech enterprises is significantly and positively related to their profitability [2]. However, Liu et al. (2020) found that the effect of R&D investment on enterprise performance is not significant and may even have a negative impact on enterprise performance [3]; Dai et al. (2013) concluded that too low and too high R&D investment will weaken the impact on enterprise performance [4]. Some scholars also found that the relationship is non-linear, such as Zhao Yi et al. (2021), who found that R&D intensity and firm performance have an inverted V-shaped relationship, and R&D investment can only promote firm performance when the output size is maintained at a certain level [5].

The diversity of research results indicates the complexity of the relationship between the two. In order to deeply investigate the mediating role of productivity between R&D investment and firm performance, this paper uses total factor productivity as a bridge and sets control variables such as firm size in order to reduce the differential impact of sample heterogeneity on the research results and enhance the credibility of the research results.
3. Mechanism Analysis and Hypothesis

R&D investment, as an effective means for enterprises to improve their performance, gives them a significant advantage in the market competition, which results in considerable performance. The significant positive incentive of state R&D subsidies on enterprise performance makes R&D investment an important factor to drive enterprise performance improvement. Accordingly, this paper proposes research hypothesis H1.

H1: There is a significant positive relationship between R&D investment and firm performance.

Corporate performance is influenced not only by internal factors but also by external market uncertainties. On the other hand, firm performance is likely to have a feeder effect on R&D investment. Total factor productivity reflects the level of production technology and its growth rate is often considered as an indicator of technological progress, but the growth of total factor productivity does not guarantee the growth of firm performance. Therefore, this paper introduces total factor productivity as a mediating variable in exploring the relationship between R&D investment and firm performance, and proposes hypothesis H2.

H2: Total factor productivity of firms plays a mediating and facilitating role in the effect of R&D investment on firm performance.

4. Research Design and Empirical Analysis

4.1 Research Sample and Model Construction

In this paper, China GEM listed companies from 2012-2019 are used as the research sample and treated as follows: (1) exclude non-A-share, financial industry and ST listed companies; (2) exclude companies with missing and abnormal variables; (3) exclude some companies whose total factor productivity cannot be matched. Finally, 10,172 valid observation samples were obtained. STATA software was used for data processing, and the relevant data used in this paper are obtained from the CSMAR database.

In order to control the influence of other factors on firm performance, this paper draws on existing studies and sets Size, Lev, Cash, Tobing, Owner, and Hrate as control variables. The variable Ln_inv is the result after taking the logarithm of the amount of R&D investment.

Considering the influence brought by industry differences, this paper adds industry Industry variable to the empirical model for control. In addition, this paper takes into account the possible heteroskedasticity of each explanatory variable, so robust standard errors are used to control for it.

First, this paper constructs an econometric model of firm performance variables (ROA) and R&D investment (Ln_inv) to test whether H1 holds.

\[ \text{ROA} = \alpha_0 + \alpha_1 \text{Ln_inv} + \alpha_2 \text{Control} + \epsilon \] (1)

Second, this paper constructs model (2) for the mediating variable (Lntfp) and R&D input (Ln_inv), and further constructs model (3) based on model (1) to model (2) to test H2:

\[ \text{Lntfp} = \beta_0 + \beta_1 \text{Ln_inv} + \beta_2 \text{Control} + \epsilon \] (2)

\[ \text{ROA} = \gamma_0 + \gamma_1 \text{Ln_inv} + \gamma_2 \text{Lntfp} + \gamma_3 \text{Control} + \epsilon \] (3)

4.2 Correlation Analysis

The above table shows the results of Pearson correlation analysis of the main variables, in which Owner and Size are both significantly and positively correlated with ROA and Lntfp, which initially indicates that the larger the size of the firm and the higher the percentage of investors’ shareholding, the higher the internal productivity of the firm and the better the firm performance. Meanwhile, the
correlation between Size and ROA is not significant, which initially indicates that the impact of firm size on firm performance is not significant.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ROA</th>
<th>Ln_inv</th>
<th>Ln_tfp</th>
<th>Size</th>
<th>Lev</th>
<th>Cash</th>
<th>Tobing</th>
<th>Owner</th>
<th>Hrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROA</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln_inv</td>
<td>0.1199**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln_tfp</td>
<td>0.1089**</td>
<td>0.5712**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>0.0032</td>
<td>0.6021**</td>
<td>0.8274**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lev</td>
<td>-0.3521**</td>
<td>0.2503**</td>
<td>0.5348**</td>
<td>0.5514**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash</td>
<td>0.2416**</td>
<td>-0.0788**</td>
<td>-0.1978**</td>
<td>-0.2488**</td>
<td>-0.3947**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tobing</td>
<td>0.1974**</td>
<td>-0.1754**</td>
<td>-0.3369**</td>
<td>-0.394**</td>
<td>-0.3125**</td>
<td>0.1677**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner</td>
<td>0.1813**</td>
<td>0.0818**</td>
<td>0.1356**</td>
<td>0.1543**</td>
<td>-0.0781**</td>
<td>0.1332**</td>
<td>-0.0779**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hrate</td>
<td>-0.0177**</td>
<td>0.0318**</td>
<td>-0.0236**</td>
<td>0.0091</td>
<td>-0.0242**</td>
<td>0.0361**</td>
<td>0.0483**</td>
<td>0.0509**</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: "****", "***", and "**" represent significant correlations at 1%, 5%, and 10% confidence levels (two-sided), respectively, as below.

Ln_inv is significantly and positively correlated with ROA, indicating that R&D investment contributes to the improvement of firm performance. Except for the Size variable, all the other variables are significantly correlated with the explanatory variables, and the absolute values of the correlation coefficients between the variables are significantly less than 0.5, which tentatively determines that there is no serious problem of multiple co-linearity among the main variables, and the selected variables are suitable for regression analysis.

4.3 Regression Analysis

This paper draws on the mediation effect test of Wang et al [6] to test the mediation effect of innovation input: (1) regress the explanatory variable (Ln_inv) on the explained variable (ROA), and if the regression coefficient α1 is significant, the theory is established by the mediation effect. (2) Regress the explanatory variable on the mediating variable (Ln_tfp) and observe whether the coefficient β1 is significant. (3) Regress the explained variable and the mediator variable on the explained variable at the same time, and observe whether the regression coefficients γ1 and γ2 are significant. If both β1 and γ2 are significant, the indirect effect of the explanatory variable is significant; if γ1 is significant, the direct effect is also significant. (4) Compare the sign of β1 × γ2 with that of γ1. If the sign is the same, it means that the mediating variable (Ln_tfp) has a partial mediating effect; if the sign is different, the mediating variable plays a masking effect. From the results of model (1) to test the relationship between enterprise R&D investment and enterprise performance, the regression coefficient α1 of R&D investment is 0.007 and is significant at the 1% level, indicating that R&D investment helps to significantly improve enterprise performance, which verifies the H1 hypothesis.

The regression results of model (2) show that the regression coefficient β1 of enterprise R&D investment and enterprise total factor productivity is significant at the 1% level, and enterprise R&D investment is significantly and positively related to enterprise total factor productivity. Model (3) adds a mediating variable to model (1) to test the mediating effect of total factor productivity in the relationship between R&D investment and firm performance. The regression results show that the regression coefficient of total factor productivity γ2 is 0.0292, which is significant at the 1% level, and the regression coefficient of R&D investment γ1 is 0.0031, which is also significant at the 1% level, and β1 × γ2 has the same sign as γ1, indicating that the direct and indirect effects of R&D investment are significant in the mediating effect model, and total factor productivity plays a partially mediating role in the relationship between R&D investment and firm performance in the current period. H2 holds because total factor productivity plays a partly mediating role between R&D investment and firm's current performance.
The mediating effect is $\beta_1 \times \gamma_2 = 0.1342 \times 0.0292 = 0.0039$, the total effect is $\alpha_1 = 0.007$, and the percentage of the mediating effect to the total effect is $\beta_1 \times \gamma_2 / \alpha_1 = 55.71\%$. This indicates that firms’ capital investment in research and innovation can highly influence the total factor productivity of firms, effectively driving up their internal productivity and thus improving their current performance, and innovation investment plays a partially mediating role in this process.

In terms of control variables, the regression coefficients of firm size Size and total factor productivity are positive and the regression coefficient of ROA is negative, both significant at the 1% level. This indicates that when an enterprise matures and expands in size, it enters a stable period of development and forms a scale effect, which naturally enhances productivity. However, enterprise size and enterprise performance do not constitute an absolute positive relationship, and sometimes, the relative expansion of enterprise debt will have a negative impact on enterprise business performance.

The value of Tobin’s Q can reflect the growth ability of a firm, which is not significantly related to total factor productivity, but significantly and positively related to firm performance. The growth ability of a firm is generally linked to the growth rate of net profit, which not only takes into account internal costs but also external factors, and therefore has a weak relationship with total factor productivity and a significant relationship with internal performance.

The percentage of independent directors has a significant negative relationship with total factor productivity and corporate performance, indicating that the higher the percentage of independent directors, the lower the productivity and corporate performance within the firm in general. It is believed that the higher the percentage of independent directors, the lower the volatility of corporate performance.

The level of cash holdings and the increase in the shareholding of top ten shareholders bring positive effects on both total factor productivity and firm performance.
4.4 Test of Model Soundness and Consensuality

1. Robustness test

In order to improve the reliability of the robustness test of the mediating effect, this paper uses robustness standard errors to control for them, and controls for industries, and conducts the following robustness tests: model (5) is shown in Table 3, and ROE is selected as a proxy for corporate performance, and the regression coefficients are all in the same direction, and the explanatory variables, mediating variables, and control variables are significantly correlated with the explanatory variables, and the regression results still support the paper's main conclusions of this paper; model (6) selects EPS as a proxy indicator, and the direction and coefficient significance of all variables are the same as model (4) except for Size and Hrate, and the regression results also support the previous conclusions.

2. Endogeneity test

According to the current policy, the pre-tax deduction ratio of R&D expenses is as high as 75%, and the higher the financial performance of an enterprise, the more abundant its capital is, the more likely it is to invest in R&D and innovation areas, and the high performance is also likely to increase the enterprise R&D investment, so there may be a reverse causal relationship between enterprise R&D investment and enterprise performance.

In order to control the impact of the resulting endogeneity problem on the research results, this paper selects lagged one-period data of the independent variables for the regressions, with a total sample of 10,172. The regression results after adjusting for robust standard errors are consistent with the previous findings, and the endogeneity problem arising from reverse causality is preliminarily excluded.

To further control for potential endogeneity, this paper draws on the study of Liu et al [7] and selects total factor productivity as an instrumental variable for R&D investment, using a two-stage least squares approach to develop the analysis. Total factor productivity is related to R&D investment, and R&D results can be directly invested in firm production to drive efficiency. Ceteris paribus, the correlation between total factor productivity and firm performance is smaller than that with R&D expenses.
investment due to the interference of external uncertainties, thus satisfying the correlation condition of the instrumental variable. Table 4 presents the main regression results, and the second-stage regression results show that R&D investment is significantly and positively correlated with firm performance, which is consistent with the previous findings.

**Table 4.** Endogeneity test results

<table>
<thead>
<tr>
<th>Variable</th>
<th>First-stage Regression</th>
<th>Ln_inv Second-stage Regression</th>
<th>ROA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrumental Variable</td>
<td>Coef.</td>
<td>t</td>
<td>Coef.</td>
</tr>
<tr>
<td>Ln_tfp</td>
<td>0.4576***</td>
<td>25.7</td>
<td></td>
</tr>
<tr>
<td>(0.0178)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln_inv</td>
<td></td>
<td></td>
<td>0.0668***</td>
</tr>
<tr>
<td>(0.0032)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>10172</td>
<td></td>
<td>10172</td>
</tr>
<tr>
<td>R²</td>
<td>0.6284</td>
<td></td>
<td>0.0000</td>
</tr>
<tr>
<td>Adj R²</td>
<td>0.6257</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After further controlling for the endogeneity problem through the instrumental variables approach, the regression results remain significant, which proves the robustness of the paper's findings.

5. **Conclusion**

This paper empirically investigates the impact of R&D investment on firm performance and verifies whether total factor productivity plays a mediating and facilitating role in the impact path, using a sample of GEM listed companies from 2012-2019. It is found that (1) R&D investment has a significant improving effect on firm performance; (2) total factor productivity plays a partial mediating effect between R&D investment and firm performance, i.e., R&D investment has a direct impact on firm performance, but also can indirectly improve firm operating performance by promoting firms to improve internal productivity.

Based on the findings, this paper proposes the following recommendations: GEM listed companies, as the mainstay of high-tech industry, should regard scientific research and innovation as their core competitiveness, and the government should support and encourage them by stimulating their independent R&D through policies such as tax exemptions and fees. Enterprises themselves should also improve resource allocation efficiency and increase investment in innovation. The positive impact on total factor productivity within enterprises is often not immediate due to the long and risky R&D return cycle, so enterprises need to continuously promote innovation activities to form a virtuous cycle and enhance long-term performance.

There are still shortcomings in this study, which need to be improved and perfected. First, the research sample needs to be further subdivided; second, the stability test can use other indicators that better reflect the performance of enterprises, which is conducive to a more in-depth investigation of the relationship between R&D investment and enterprise performance and ensure the reliability of the model.

**References**


