THE EMPIRICAL STUDY OF THE IMPACT OF R&D HUMAN RESOURCE INVESTMENT ON INNOVATION PERFORMANCE

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ABSTRACT

High-tech firms have been the main impetus of economic growth and prosperity, innovation is the key to high-tech firms' development. So an exploration of the influencing factors of high-tech firms' innovation performance can serve as a reference in promoting national and regional economic development. With the data collected from the 166 high-tech firms, the impact of R&D human resource investment on innovation performance are explored from the resource-based view. The R&D human resource investment is measured by four dimensions, namely R&D human resource intensity and quality, R&D human resource training and compensation. The innovation performance is measured by the number of authorized utility patents and new product sales respectively. By using modified Cobb-Douglas production function and Multilevel linear regression analysis .The results indicate that R&D human resource investment has more significant influence on authorized utility patents than on new product revenue compared with R&D expenditure investment. In particular, R&D human resource intensity and quality show only positive impact on authorized utility patents; R&D human resource training shows only negative impact on authorized utility patents numbers; R&D human resource compensation has positive influence on authorized utility patents and new product revenue. Finally, the causes of the results are analyzed and suggestions to improve the utilization of R&D human resource investment so as to improve innovation performance are proposed.

Key words: R&D human resource investment; R&D human resource training; R&D human resource compensation ; innovation performance

INTRODUCTION

With the trend of economic integration and intensifying competition, Innovation has been regarded as a critical enabler for firms to gain competitive advantage in the increasingly complex and rapidly changing environment (Subramaniam and Youndt,2005) .Compared with the traditional firms, the high-tech firms are characterized by high emphasis on innovation, high investment in R&D activities and a large accumulation of R&D employees, making them better equipped to respond quickly to the fast-changing environment and exploit new technologies and market opportunities. Scholars have investigated the underlying factors which influence high-tech firms' innovation performance. Li et al (2015) find that "the R&D human resource investment, internal R&D expenditure, external technical support and government intervention have varying influence on high-tech firms' innovation performance". Zhang et al(2013) empirically find that" the scale of firm, R&D investment,

technical efficiency are important influencing factors of high-tech firms' innovation performance". Among all the influencing factors, the role of R&D expenditure has already been intensively investigated, and scholars are more interested in the role of R&D human resource investment, as Collins and Smith(2006) propose that "the R&D human resource play a vital role in promoting innovations".

According to the Resource-based view, firms are heterogeneous in terms of the resources they control, among all the resources human resource provide a rare and incomparable source of competitiveness (Barney,1991). Especially for the high-tech firms, they have a large accumulation of R&D employees, which constitute the most important strategic assets of firms. In accordance to the knowledge management theory, R&D employees are the primary source and main body of knowledge accumulation and generation, firms can generate innovation by managing the knowledge possessed by the R&D employees, indicating that R&D human resource is increasingly becoming the backbone of firms' innovation performance. Strategic human resource scholars have also argued that firms can effectively influence the interactions, behaviours, and motivation of employees through efficient human resource investment. R&D human resource investment is regarded as the most important input for the advancement of science and technology, and the R&D human resource investment and innovation performance then are tightly intertwined.

Despite the wide recognition of the importance of human resource investment for innovation, empirical study of the impact of human resource investment on innovation performance is scarce. Our research attempts to fill this gap by empirically investigating the relationship between R&D human resource investment and innovation performance using high-tech firms' data. Specifically, we compare the different impact of R&D human resource investment and R&D expenditures on innovation performance.

From the perspective of the resource-based view, we introduce a model of how R&D human resource investment influences innovation performance. We develop this model by first defining R&D human resource investment in terms of the intensity and quality of R&D human resource investment, R&D human resource training investment and compensation investment respectively, as these four practices are closely related with R&D employees' behaviour and motivation. Innovation performance is measured by the number of authorized utility patents and new product sales respectively. We then conceptually and empirically connect these investment practices to innovation performance by using Modified Cobb-Douglas production function and Multilevel linear regression analysis on a sample of 166 high-tech firms. The empirical results have important practical significance in guiding high-tech firms especially to optimize R&D human resource investment and thus improving innovation performance.

THEORETICAL BACKGROUND AND CONCEPTUAL FRAMEWORK

The intensity of R&D human resource investment and innovation performance

Jones and Schneider (2006) argue that "human resource is an abstract concept referring primarily to skills and knowledge, which means that employees with better skills and knowledge are more likely to effectively develop and implement innovations". Since the innovative capability of a firm depends on the creativity and intelligence of its employees, the accumulation of R&D human resource investment can help create a good learning atmosphere and knowledge base which enhances the

absorptive ability of employees, which is a key factor behind firms' technological progress and innovation performance. A large stock of R&D human resource can not only contribute to a higher productivity but also a continuous growth of productivity as well(Ballot et al ,2001) .Gu et al (2004) empirically find that "the investment of R&D employees have more significant impact on high-tech industry' s innovation performance than R&D expenditure input based on the economic panel data from 1995-2001". Ma et al(2013) empirically find that"1% increase in R&D employee intensity input will contribute to 0.121 increase in innovation performance for emerging industries". Based on the above arguments, we measure the intensity of firms' R&D human resource investment in terms of the number of researchers firms have and propose the following hypothesis:

H1: The greater the intensity of firms' R&D human resource investment, the greater their innovation performance is.

The quality of R&D human resource investment and innovation performance

Smith(2005) proposed that the high education background and abundant knowledge diversity will lead to high success rate of new product development. According to knowledge management theory , knowledge is a renewable resource that employees acquire through formal education and "on the job "socialization and training(Grant 2003) . Hoffman et al. (1998) have shown that highly educated R&D human resource enhance the innovation capacity of firms by promoting the absorption, transformation and creation of new technologies. Nelson and Phelps (1966) and Benhabib and Spiegel(1994) argue that education increases the capacity to innovate and fostered the adoption of new technologies, since the ability to receive, decode, and understand information can be greatly enhanced through education, specifically they pointed out that the number of persons having university diplomas is positively correlated with innovation . Filippetti(2011) proposed that as the innovation activity requires a highly skilled and creative employees, which are equipped with flexibility and tolerance against uncertainty and ambiguity, while these qualities do not come overnight, but they need consistent nurture through education . Based on the above arguments, we measure the quality of firms' R&D human resource investment in the terms of the education level of firms' R&D human resource and propose the following hypothesis:

H2: The greater the quality of firms' R&D human resource, the greater their innovation performance is.

R&D human resource training and innovation performance

With the rapid development of technology, it is imperative that skills and knowledge of R&D employees are up to date , which can be achieved through training, as training can provide the latest knowledge and develop employee expertise at firm level. Many scholars propose that training can help develop skills and knowledge of employees needed for innovation (Beatty and Schneier 1997; Mabey and Salaman 1995).Becker (1964) proposes that "in accordance to the human capital theory, investment in knowledge, skills and competencies would enhance the productivity of human resource". In this way training for employees has been constantly emphasized for that they are deemed to contribute to a great variety of expertise and innovative ideas within the firms. Empirical studies also have confirmed a positive relationship between training provided to employees and innovation (Mark and Akhtar 2003). Dearden et al. (2006) argue that "there exists a positive correlation between training and sector productivity, especially 5 %increase in the proportion of

workers trained will contribute to a 0.04 increase in value-added per worker", so knowledge capitalization through training is crucial for the enhancement of innovation performance . Van Ark et al (2008) find that" the investment in training is directly related to the improvement of the human capital, and thus having a positive impact on the enhancement of innovation performance". Ballot et al(1998) calculate the training stock of 200 large firms by aggregating their employee expenditure and conclude that they are positively correlated with the innovation performance. Based on the above arguments, we assume that firms should spent more money on training to increase the innovation performance and propose the following assumptions:

H3: The greater the spent of firms on training for R&D human resource, the greater their innovation performance is.

R&D human resource pay incentive and innovation performance

The high qualified R&D human resource input can not guarantee high innovation performance without an effective incentive mechanism to guide employee behaviour and mobilize their working enthusiasm. As Becker(1962)proposed that" it is imperative to properly compensate employees for skills and knowledge that contribute to innovation". The absence of right compensation incentives will greatly restrict innovative behavior and performance for skilled R & D human resource. Huselid (1995) has shown that "compensation incentives plays an increasingly important role in influencing employees' awareness for organization rewards and ultimately affect employees' conduct". If employees feel that they are valued by firms and get what they work for in a reasonable way, they will engage in the R&D activities more actively and generate more new ideas and inventions, otherwise they will feel negative inequity, thus are motivated to eliminate this unpleasant feeling by engaging in counterproductive work behaviour or resigning from the firm directly, which may greatly inhibit organizational innovation. Chen and Huang (2009) propose that "in order to enhance innovation performance, the compensation incentives should be designed specifically to engender creativity, problem solving ability". Gupta et al (2007) propose that "compensation design constitute a key part of organizational pay incentive structures", appropriate compensation level is vital to guide employee behaviour and mobilize their working enthusiasm on the base of self-interest. Bu et al (2010) empirically find that "the high compensation level will reduce the employee turnover rate and significantly improve firms' performance". As Balkin et al(2000) propose that "there is a positive relationship between employee compensation level and innovation performance". The extrinsic compensation level is essential to induce employees to work actively. In summary, we propose the following assumption:

H4: The greater the spent of firms on high compensation for R&D human resource, the greater their innovation performance is.

RESEARCH METHODOLOGY

The sample and data

With the data collected from the evaluation of provincial enterprise technology center in Hubei province in 2013, initiated by Hubei provincial development and reform commission, aiming to strengthen the technology innovation management of firms. We finally get 166 high-tech firms' data out of 210 firms approached, with the response rate of 79.05%, since some firms have the missing

values in terms of new product revenue. The firms in our sample mainly covers areas such as pharmaceuticals, electronics information, new materials, aerospace et al, which are characterized by a large stock of R&D human resource investment and R&D intensity. The sample set is quite representative and meaningful for the empirical analysis.

The measures

Dependent variable---Innovation performance

How to evaluate the innovation performance effectively has been a controversial debate for scholars. They have developed different indicators according to their research purposes. Among them patent has been considered to be the best innovation performance indicator which reflect the fundamental innovation ability of firms. Hagedoorn et al(2003) mainly use the patents and patent citations to represent innovation performance. Yanadori et al (2013) propose that "patent is regarded as an important performance indicator especially for the fact that the R&D human resources are the major workforces for generating new inventions". Especially for the authorized utility patents, which have been strictly examined and approved by the official department, the number of which can represent the innovation capacity of firms directly and objectively and is widely used by scholars. While Patents alone may often underestimate or overestimate innovation performance (Fritsch & Slavtchev, 2009; Romijn & Albaladejo, 2002).Some studies have considered to take new product rate or sales as another innovation output indicator, as new products reflect the commercialization ability of inventions. So in this paper we measure the innovation performance of firms from the number of authorized utility patents and new product sales respectively(Li et al, 2015).

Independent variable---R&D human resource investment

We measure R&D human resource investment from the following four aspects, namely the intensity and quality of R&D human resource investment, the R&D human resource training investment and R&D human resource compensation investment.

The intensity of R&D human resource investment can be measured by the number of researchers engaging in R&D activities as most scholars do(Li et al, 2015), the rationale is that these researchers reflect the true level of human resources invested by firms in innovation process, as they are the most important drivers of innovation processes. Brenner and Broekel (2011) measure the number of innovation generators from the perspective of R&D employees in firms, they perceive them to be closely related to innovation performance.

The quality of R&D human resource investment can be measured by the education level of the R&D employees. As Gao et al(2012) measure the strategic human capital investment from the perspectives of educational level of its employees ,they perceive that human capital is the accumulation of knowledge and experience through education nurturing, thus the education level can reflect the ability and quality of its employees most directly and vividly.

The R&D human resource training investment is measured by the amount of money firms spent on training for R&D human resource, as Die´go(2011) defines training expenditure as a new source in the knowledge production function. Ballot(2001) also takes the training stocks as a significant input in the production function, especially for the French firms, they have continuously increase the

money spent on training, positive return from training investment are found as well. The R&D human resource compensation investment is measured by the average salary pay per year for the R&D human resource , as Balkin et al(2000) find that "the salary level of employees are positively correlated with innovation". Tsai and Wang(2015) also find that "higher salary levels for employees will lead to higher productivity".

Control variables

In this study, we take other important factors that influence innovation performance as control variables, the R&D expenditure and firm size are treated as control variables. The firm size is measured by the total number of employees firms have(Zhang et al,2013, Yanadori et al,2013), as big firms are more likely to undertake R&D activities and realize greater innovation performance as a result of economies of scale. R&D expenditure is found to be closely correlated with innovation performance, as they can provide enormous technical resource support and guarantee for the successful implementation and function of R&D activities. The R&D expenditure is normally measured by the amount of money firms spent on research and development (Yoshio et al,2013).

Table 1: The measurement indicators of R & D human resource investment and innovation performance

Variables		Proxy variables	Measurement
independent variables	R&D human resource Investment	R&D HR intensity（L1）	The number of researchers engaging in R&D activities
		R&D HR quality(L2)	The number of employees having masters degree and above
		R&D HR training (L3)	The amount of money firms spent on training for R&D HR
		R&D HR compensation (L4)	The average salary of R&D HR per year
control variables	R&D expenditure	R&D expenditure (K)	The amount of money firms spent on research and development.
	firm size	Firm size (S)	The number of total employees firms have
dependent variables	Innovation performance	New product sales(NPS)	New product revenue this year (×10000¥)
		Authorized utility patents (P)	The quantity of authorized utility patent this year

Descriptive statistics analysis

Table 2 displays the means, standard deviations, and correlations of all variables. Variance inflation factors(VIF) are used to examine the effect of multicollinearity between the independent variables. The value of the VIF show a range from 1.68 to 3.9, which fall within the acceptable limits, therefore

there is no significant collinearity between the variables. The descriptive statistical analysis is shown as in the following table 2. For the four dimensions of R&D human resource investment, the average R&D human resource intensity(L1) which is measured by the total number of researchers is 167.85, representing that firms enjoy a comparative high R&D human resource intensity; whereas there exists a serious phenomenon of polarization, as the standard deviations are much higher than the means for the independent variables, which is also reflected in the R&D human resource quality , training and compensation investment. In terms of the innovation performance, the average quantity of authorized utility patents is only 3.83, which needs to be enhanced greatly. Table 2 shows that the four dimensions of R&D human resource investment are closely correlated with the innovation performance from the Pearson correlation analysis. The impact of R&D human resource investment on innovation performance needs further investigation.

Table 2: Descriptive statistics analysis

Variables	Mean	SD	1	2	3	4	5	6	7	8
1R&D expenditure (k)	5609.21	6589.46	1.000							
2 firm size (S)	1441.24	2661.53	0.522	1.000						
3 R&D HR intensity (L1)	167.85	169.59	0.533	0.473	1.000					
4 R&D HR quality (L2)	13.04	20.51	0.331	0.277***	0.340	1.000				
5 R&D HR training (L3)	101.7	183.33	0.057*	0.052**	0.069	0.04**	1.000			
6 R&D HR compensation	4.26	1.91	0.224***	0.089*	0.188**	0.305***	-0.008	1.000		
7 New products sales (NPS)	50797.3	69633.2	0.562***	0.522***	0.482***	0.279***	0.077**	0.296***	1.000	
8 Authorized utility patents	3.83	5.141	0.551***	0.416***	0.471***	0.361***	0.052**	0.276***	0.373***	1.000

NOTE： p<0.05; ** p<0.01; *** p<0.001*

EMPIRICAL RESULTS AND ANALYSIS

Multiple linear regression model

The relationship between R&D human resource investment and innovation performance is traditionally interpreted as a knowledge production function. Based on endogenous growth theory and Cobb - Douglas production function, the R&D human resource investment and R&D expenditure are chosen as endogenous variables in production function, in which the firm size is chosen as a control variable, the modified Cobb - Douglas production function is as follows:

$$Y_i = A K_i^{\alpha} L_i^{\beta} S_i^{\gamma} \quad LogY_i = LogA + \partial Log K_i + \beta Log L_i + \gamma Log S_i + \varepsilon$$

Where, K represent the control variable R&D expenditure , L is the generic terms of the independent variable R & D human resource investment , in which L is represented by R&D human resource intensity(L1), the quality of R&D human resource investment(L2), R&D human resource training(L3) and compensation (L4) respectively. S is the control variables firm size, Y respectively, is the number of authorized utility patent and new product sales.

Empirical Analysis

Multiple regression analysis is used in this study, the number of authorized utility patents (P)and new product sales(NPS) are chosen as dependent variable respectively, R & D human resource intensity(L1), the quality of R&D human resource investment (L2), R & D human resource training(L3) and compensation(L4) are independent variables , R & D expenditure (k)and firm size(S) as control variables in the multiple linear regression model, the results are shown in Table 3.

Table3:Multiple Regression Analysis

The independent variables	The dependent variables (Authorized utility patents)	The dependent variables (New product sales)
	The coefficients B	The coefficients B
R&D HR intensity(L1)	0.410***	-0.144
R&D HR quality (L2)	0.099**	-0.032
R&D HR training(L3)	-0.168***	0.045
R&D HR compensation (L4)	0.264*	0.244*
R&D expenditure(k)	0.243***	0.618***
Firm size(S)	-0.074	0.347***
F value	18.360***	75.874***
R^2	0.282	0.618
Adjusted R^2	0.266	0.610
Standard error	0.379	0.331
D-W	2.071	1.767

NOTE ： $p<0.05$; ** $p<0.01$; *** $p<0.001$*

Table 4: Multiple Regression Analysis

The independent variables	The application for patents	New product sales
R&D HR intensity	0.410***	-0.144
R&D HR quality	0.099**	-0.032
R&D HR training	-0.168***	0.045
R&D HR pay incentive	0.264*	0.244*
R&D expenditure	0.243***	0.618***
Firm scale	-0.074	0.347***
F value	18.360***	75.874***
R2	0.282	0.618
Adjusted R2	0.266	0.610
Standard error	0.379	0.331
D-W	2.071	1.767

Multiple Regression Analysis results

The regression analysis results is shown in Table 3, D-W values are 2.071 and 1.767 ,which are close to 2, indicating that the error terms in the model described are independent. Adjusted R^2 were 0.266 and 0.610, P equal to 0.000, indicating that the model has very good explanatory power. The coefficient β is reported in the empirical analysis, such as the coefficient β between human resource intensity and the authorized utility patents is 0.410(β =0.410 and p<0.001), representing that the human resource intensity has profound positive impact on the authorized utility patents.

The impact of R&D human resource intensity and quality on innovation performance

The intensity and quality of R&D human resource have the same effect on innovation performance, both of them have a significant positive impact on authorize utility patents. The 1% increase in value of R&D human resource intensity will lead to 0.41   increase of the authorized utility patents numbers. Comparatively 1% increase in value of R&D expenditure will lead to 0.243 increase of the authorized utility patents numbers (β =0.243 and p<0.001), representing that the accumulation of R&D employees play a larger role in enhancing high-tech firms' patent output performance than the R&D expenditure investment. The 1% increase in value of R&D human resource quality(measured by the number of employees having masters degree and above)will lead to 0.099 increase of the authorize utility patents numbers (β =0.243 and p<0.01) . R&D human resource is the major asset for innovative organization, the knowledge they owned is the most important critical resource which stimulate firms' innovation capacity, thus enhancing the R&D capability in the form of patent. These findings indicate that firms will achieve a higher level of innovation performance in terms of patents if they have a large stock of highly-educated R&D employees. The results partly support both Hypothesis 1 and 2, whereas both the intensity and quality of R&D human resource investment

show no direct impact on new product sales. As Feng(2010) empirically find that the investment of R&D employees has a negative impact on new product sales as a result of decreasing marginal revenue caused by poor people management. Apart from this managerial inefficiency, there are two main reasons to account for this phenomenon, On the one hand it's caused by time lag between R&D human resource investment and new product sales, the commercialization of new inventions and ideas need a long process of trials and errors, what' s more, the new product is not immediately effective once put into the market, thus the positive effect of highly educated R&D employees have not yet been fully displayed. On the other hand, it also reflects that the new product development is not combined with market demand very closely, resulting in a lack of product commercialization conversion capacity, previous study has found that the lack of commercialization of patents has always been a bottleneck of technology innovation.

The impact of R&D human resource training on innovation performance

The R&D human resource training have a significant negative impact on authorized utility patents numbers, whereas it has no direct impact on new product sales. The 1% increase in value of money spent on R&D human resource training will lead to 0.168 decrease of the authorized utility patents numbers (β =-0.168 and p<0.001 for the interaction between training and the authorized utility patents numbers) ,which is contrary to the traditional theoretical viewpoint that money spent on training for R&D human resource can significantly promote innovation performance .Laursen & Foss (2003) have found that "the positive impact of training on innovation performance depends highly on the form and effect of the training". Through the corporate interviews we undertake, we get to know that the training most firms take are not tailor-made for the researchers engaging in R&D activities, instead most of the trainings are more concerned about the generic skills, the managers are more concerned about formalism of training rather than the substance and essence of the training itself. As a consequence of the poor functioning of training, they fail to benefit the R&D employees. What' s more, the firms' notion toward training needs to be changed as well ,as most firms interviewed report that trainings for the R&D employees are not taken seriously , as they perceive that training only benefit the employees since firms are suffering from a terrible brain drain. This phenomenon is common and universal in most high-tech firms, the huge money spent on training cannot guarantee the effect of the training itself.

The impact of R&D human resource compensation on innovation performance

The R&D human resource compensation investment has significant impact on both authorized utility patents numbers and new product sales, the 1% increase in value of R&D human resource compensation investment will lead to 0.264 increase of the authorized utility patents numbers and 0.244 increase of new product sales. As previously described in the literature review, the appropriate compensation level can consolidate the material foundation for employees and provide them with a working sense of superiority and work identity, thereby enhancing the employee initiative and enthusiasm. Therefore, the innovation performance of firms can be effectively enhanced by improving employee productivity through the adoption of higher compensation incentive system .

CONCLUSIONS AND IMPLICATIONS

Conclusions

Based on the data of 166 high-tech firms in Hubei Province, the impact of R&D human resource investment on innovation performance are examined through the integrated use of Pearson correlation analysis and modified Cobb - Douglas production function, we can draw the following important conclusions:

a. The empirical results indicate that compared with R&D expenditure, R&D human resource investment has more significant influence on authorized utility patents numbers. Namely the intensity and the quality of R&D human resource investment show greater impact on authorized utility patents numbers compared with the R&D expenditure investment, since the authorized utility patents comes directly from the knowledge utilization and creation of the R&D employees. R&D human resource training show only negative impact on authorized utility patents numbers, which is quite contrary to the traditional argument ; Whereas the R&D human resource compensation investment has positive influence on both authorized utility patents numbers and new product sales, reflecting that high compensation level can greatly boost the enthusiasm of the R&D human resource, thus promoting the creation of new inventions and ideas.

b. The R&D human resource investment should be taken as a bundle of practices in a systematic way. The single dimension of R&D human resource investment is positively correlated with the innovation performance separately from the Pearson correlation analysis. Whereas after adding other dimensions of R&D human resource investments, the original positive impact will disappear, even turn from the positive to negative. Take the intensity of R&D human resource investment as an example, as is indicated in the Pearson correlation analysis, it is closely correlated with patent and new product output, while after adding R&D training and R&D compensation investment in the regression analysis, the original positive impact on authorized utility patents numbers is not significant any more. The results suggest that firms' innovation performance are influenced by the compound mixed effects of R&D human resource investment instead of the single dimension of R&D human resource investment. The R&D human resource investment should be regarded from the systematic view which is characterized as a high degree of integration and complementarities, so we can not count on to improve the innovation performance by enlarging one particular dimension of human resource investment at the expense of other dimensions. By contrast more and more emphasis should be put on the overall optimization of the allocation between different dimensions of R&D human resource investments.

c. The enormous money firms spent on training fails to reach the desired positive effect, which is indicative of the poor implementation of training .It raises immediate alarm for the managers to make specific and targeted adjustment to improve the functioning of training, more emphasis should be put on improving the quality of the training for the employees, training should be taken as a corporate strategy and be designed specifically to enhancing employees' innovation capacity. Only in this way can the firms truly benefit from the investment in training for the R&D human resource.

Implications

i. From the theoretical level, this empirical research makes initial inroads into the theoretical bases of R&D human resource investment as they pertain to innovation performance. Specifically, R&D human resource investments are shown to generate superior authorized utility patents numbers. Namely the intensity and the quality of R&D human resource investment show greater impact on authorized utility patents numbers, which is vital to researchers, since it identifies a new innovation driver than previously conceived. What's more, we especially focus on the R&D employees instead of all the employees in the firms, making our investigation more specific and relevant. We take not only the authorized utility patents numbers but also new product sales as indicators of innovation performance, and empirically investigate the different impact of R&D human resource investment on them, which provide a detailed explanation of the influencing factors of different dimensions of innovation performance.

ii. From the managerial level, the findings suggest that firms competing on innovation should invest in optimizing R&D human resource investment to benefit from the high quality employees. Firms' priority is to attract highly-qualified R&D human resource and enlarge its spent on compensation for the R&D human resource so as to mobilize their working enthusiasm. Managers are also cautioned to prevent overemphasizing the money spent on training for R&D human resource, but pay more attention on how to diversify the form of training and optimize the effect of training on employees. The lack of commercialization of patents has raised alarm as well, since both the intensity and quality of R&D human resource has not shown positive impact on new product sales, which reflects that the research and development of new products is not closely connected with the market demand, so the new product sales fail to benefit from the highly-qualified R&D human resource investment. The market-based innovation strategy should be adopted by firms and more favourable conditions should be created for the R&D human resource so as to better play their mental and intellectual effects.

Limitations and future research

This study has some limitations. The first limitation is the implication for the generalisation of the empirical finding, as we focus on high-tech firms and take them as the specific example, whether the empirical findings of R&D human resource investment' impact on high-tech firms' innovation performance applies to other traditional firms or not still needs further investigation and research. The second limitation is the shortage of our sample data, with only one year's data of high-tech firms, there will be a lag effect in the relationship between R&D human resource investment and firms' innovation performance. Future research will overcome these limitations by using a longitudinal panel data and investigate the different impacts of R&D human resource investment on innovation performance by industry, thus making the research result more specific and objective. Knowledge based view should be adopted to further investigate the mediating role of knowledge management capacity on the impact of R&D human resource investment on innovation performance in the future research.

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