Effects of R&D Risk on Technological Innovation Performance: The Intermediary Role of R&D Specific Human Capital

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Abstract--**Differentiation of competitive strategy and diversification of technology make R&D specific human capital more and more prominent. This paper, discusses the impact of R&D risk to the enterprise technological innovation performance, and takes R&D specific human capital as a mediating variable. Depending on the analysis of existing research and theoretical deduction, the theoretical model of this paper is built and relevant hypotheses are put forward. Finally, with using the method of questionnaire survey and data analysis, the model is verified, and the following conclusions are drawn:**

(1) Technological uncertainty, market uncertainty, competitive uncertainty and policy uncertainty are significantly negatively correlated with enterprise technological innovation.

(2) R&D specific human capital has a partial intermediary role in the impact of R&D risk on the enterprise technological innovation. R&D risk has a significant negative impact on R&D specific human capital.

I. INTRODUCTION

With development of knowledge economy, technological innovation as the source of knowledge for economic development, has become an international economic competition and a contest of comprehensive national strength. Meanwhile, the enterprises as the main body of technological innovation, especially high-tech enterprises, technological innovation competition among enterprises is becoming more fierce and product replacement cycle is becoming shorter and shorter. Technological innovations of enterprises relies on corporate R & D personnel and exclusive enterprise information resources. Due to the hard copy of the knowledge and skills, R & D personnel has become the core strength of enterprise technology innovation activities. However, technical innovation of the high uncertainty and high investment decision with a high risk of technological innovation would undermine their own human capital to improve specificity of motivation, eventually leading enterprise technology innovation adverse effects.

Based on China situtation, this paper takes researchers specific human capital as an intermediate variable, to explore the impact of R & D risks to the enterprise technological innovation performance in order to promote technological innovation to improve enterprise performance. In particular, this research will provide support for the subsequent development of risk research and help enterprises how to manage R&D risks. In summary, this paper combines important theoretical and practical significance.

II. LITERATURE REVIEW AND RESEARCH HYPOTHESIS

A. R&D risks

High uncertainty is the main feature of enterprise technology innovation [1], which determines the technical innovation development process including many risk. Scholars called these risk as development risk or innovation risk, collectively referred to herein as the R & D risk.

Concept of R & D risk is defined from consequences of enterprise technology innovation resulting from risks. For example, according to Aaron, R & D risk is defined as causing project delays, cost overruns, safety or environmental hazards, or even complete failure of the event, and that the development of risk from the R & D the project itself, the specific performance of environmental uncertainty, the lack of resources and skills, policy constraints [2]. Chaoxiang Pan and Yunzhi Liang defined risks as the development of enterprises in product development, commercialization and industrialization of the process, due to various uncertainties, research and development difficult external factors which limit the ability of the body, eventually leading to the possibility of failure of development [3]. Ogawa and Piller pointed out that with the fast-changing and diverse market, technological innovation, customer demand for market risk is increasing, there are more than 50% of innovation comes from the failure of the market changes, rather than technology innovation itself [4]. Song et al., Empirical studies have found the risk management strategy focuses on specific risk factors such as technical risk, organizational risk, market risk, which are independent of and interaction having an impact on product innovation performance [5].

In summary, major R&D risk which high-tech enterprises are facing is the risk that the process of technological innovation to the enterprise environment of uncertainty brought about by technological innovation, including technological uncertainty, market uncertainty, competition and policy uncertainty. Among them, the technological uncertainty mainly starting from the complexity of the technology itself, market uncertainty, competition uncertainty, policy uncertainty are respectively from the consumer, competitors, and the government's perspective.

1) Performance of Enterprise Technology Innovation

According to Schumpeter, innovation includes technological innovation, management innovation, market innovation, organizational innovation, which have been gradually evolved into two paths: technology innovation and

institutional innovation. Up to now, scholars has no consistent about the concept of technology innovation, but most research is related to the following two fields such as the generation of new products and processes and having a commercial value that the new products and new processes need to have economic benefits for the enterprise ability.

Technical innovation performance, as an important indicator of business technology innovation output, is the efficiency of enterprise technology process, the results of outputs and their contribution to the commercial success [6]. There are many factors affecting the innovation performance, which can be divided into internal factors and external factors. Internal factors include R & D investment, organizational culture, specific human capital, organizational strategy and corporate governance. External factors include the uncertainty of external resources and environment.

Studies have shown that the risk arising from within the R & D, the impact of external environmental factors of uncertainty for enterprise technological innovation performance is multifaceted. Song and Montoya-Weiss found that technical uncertainties affecting the partnership between the marketing department and technical departments as well as R & D managers paid more attention to development of new products, which have an impact on new product performance [7]. Canying Wu empirical research and case studies have indicated that market uncertainty, technological uncertainty on new product development performance has a significant negative impact [8]. Junzheng Feng environmental uncertainties summarized as technological developments, market dynamics, competitive and hostile policies hostile four dimensions were studied their impact on corporate discontinuous innovation [9]. Ogawa and Piller's study pointed out that with the fast-changing and diverse market, technological innovation, customer demand for market risk is increasing, there are more than 50% of innovation comes from the failure of the market changes, rather than technology innovation itself [10]. Zahara studies show that with the rise of competition in the industry uncertainty will lead to lower levels of available resources, external, internal tensions and limited cash profits, enterprises lack the motivation for technical innovation. Peng believes in property rights-based legal framework is imperfect, political instability structure, strategic factor markets immature, limiting the enterprises effective resources from the market [11], is not conducive to technological innovation to improve enterprise performance.

In summary, we hypothesize:

H1a: Technological uncertainty has a significant negative impact on enterprises' technological innovation performance.

H1b: Market uncertainty has a significant negative impact on enterprises' technological innovation performance.

H1c: Competition uncertainty has a significant negative impact on enterprises' technological innovation performance.

H1d: Policy uncertainty has a significant negative impact on enterprises' technological innovation performance.

2) Specific Human Capital

Human capital is divided into specific human capital and general human capital according to the degree of specificity. General human capital refers to the knowledge and skills of those individuals through general education and training and general experience is formed, usually including general communication skills, learning ability, management capacity or other knowledge and skills. Specific human capital refers to the skills and knowledge of employees formed depends on where the enterprise (or industry) product characteristics, market conditions, processes, corporate culture [12]. R & D personnel specific human capital refers to the development of the process of innovation in business technology officer and corporate or enterprise accumulated technological innovation projects are highly relevant knowledge or skills. Such as information, equipment knowledge and skills as well as knowledge and skills and innovation activities related to R & D personnel in the innovation process play an important role in the accumulation of the way, and work with the teamwork and the like.

Studies have shown that R&D persons are anxious for R&D risk, which lead to deficiency of specific human capital investment [13]. Dependent on Key resource theory, enterprises and R & D staffs have put specific investment into innovation projects. If the innovation projects have been devalued, specific investment from the enterprise and R&D staff will also suffer huge losses. Helfat's cases and empirical research shows that R & D staffs' avoidance of risks had a direct impact on the performance of enterprise technological innovation [14].

The analysis revealed that there were the following two paths of R & D risks affecting R&D specific human capital:

(1) R & D risks will directly affect investment decisions of business managers. Depending on managers preference for risk, R & D staff will take different measures. If the revenue is definite and the related R&D risk is higher, project investment, R & D personnel cost and so on will be inevitably reduced. Lack of R & D investment will lead to shortage R & D personnel specific human capital.

(2) R & D risks will directly affect decisions of R & D personnel dedicated human capital investment. The existed R & D risk will impact the expected return of R&D specific human capital investment. Meantime once the innovation project fails, then specific human capital investment will be devalued. Further R&D risks will possibly make R&D staff be hold up, which will make R&D staffs will choose a conservative investment approach in the investment game, thus making the R & D personnel specific human capital investment initiative inactive.

Based on the above analysis, we propose the following hypothesis:

H2a: Technological uncertainty has a significant negative impact on R & D personnel specific human capital.

H2b: Market uncertainty has a significant negative impact on R & D personnel specific human capital.

H2c: Competition uncertainty has a significant negative

impact on R & D personnel specific human capital.

H2d: Policy uncertainty has a significant negative impact on R & D personnel specific human capital.

R & D staff is the main body of enterprise technology innovation, human capital is the key to technology innovation, and specific human capital of R&D staff will maintain competitive advantage of enterprise technology innovation. Due to resource-based theory, R & D personnel specific human capital is scarce and difficult to imitate, which can bring sustainable competitive advantage for the enterprise. Barney and Heli Wang demonstrated specific human capital is a radical for high-tech enterprises to obtain competitive advantages. Aihua Wu noted that specific human capital is the foundation of the innovation process and different specific human capital will affect the validity of innovative models [15]. Wencong Ma found, in emerging industries, R & D expenditure intensity and R & D investment intensity, incentive pay and personnel training have a significant impact on innovation performance [16].

At the same time, from an economic point of view, R & D personnel dedicated human capital, which has a unique value, can meet the specific needs of enterprises to build the company's competitive differentiation. Thus, higher R & D personnel specific human capital, more heterogeneity knowledge is helpful to innovate for enterprises.

On the other hand, since the firm-specific human capital, formed in the work experience, can play role in a specific enterprise or industry effects. If leaving the industry or company, the R & D personnel specific human capital will be reduced, which help companies reduce R & D personnel turnover and enhance enterprises' technological innovation performance.

Therefore, we propose the following hypothesis:

H3: R & D personnel specific human capital have a significant positive impact on innovation performance.

Conceptual model diagram are in Figure 1.

III. RESEARCH DESIGN AND DATA ANALYSIS

A. Pre-survey and purification of scale

Scientific and effective scale is the beginning of effective research, which is also the foundation of reliability and validity. Under the consistence of each question, more question item scale is better than a single question item questionnaire, which is helpful to scale reliability. The study design is related to more latent variables, so scientific research work scale design is top priority.

For this reason, the design scale scientific design in the following process:

(1) to form a preliminary scale by literature reviewing and interviewing with the business community.
(2) to revise the scale through discussion with business experts and executives.
(3) to purify questionnaire items through testing small sample of the data.
(4) In order to reduce random answer, the questionnaire frontispiece set up a questionnaire foreword, in which academic research purpose, brief instructions and so on will be explained.
(5) As to investigation channel, authors distribute questionnaire by visiting high technology enterprises and participating industry technology conference in order to improve the quality of the scale.

About the measurement of innovation performance indicators, referring Hagedoorn & Cloodt [17], Jin Chen and Yufen Chen's [18] Indices, the scale also covers the effectiveness and efficiency of enterprise technology innovation. Measuring R & D risk, drawing Jaworski & Kohli [19], Junzheng Feng [9], Covin [20] and other scholars more mature scale from four dimensions were measured.

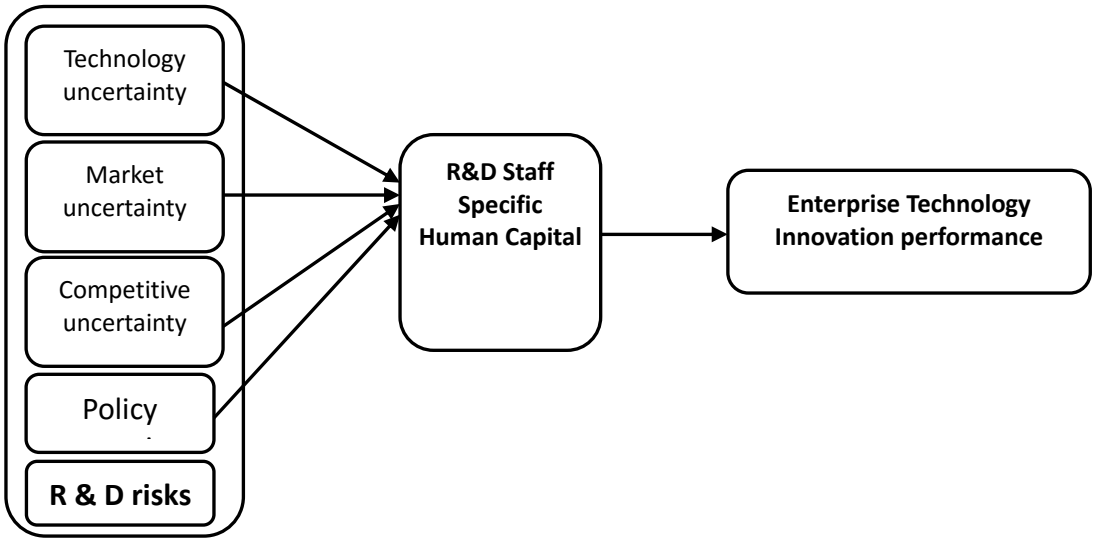

Figure 1 Concept Model of R & D Risk & Enterprise Technology Innovation Performance

Measurement of specific human capital's main draws Lepak & Snell [21], Dejun Cheng & Shuming Zhao [22] research, form eight questions of scale.

According to the research subject of the article, this data collection focused on high-tech enterprises in R & D personnel. In the questionnaire stage of the pre-survey of the author in March 2015 in Hangzhou, Shanghai, Beijing, Guangzhou and other places randomly distributed 100 questionnaires were returned 72 valid questionnaires. The effective use of questionnaires SPSS19.0 exploratory factor analysis and verification AMOS17.0 factor analysis, and their factor loadings were above 0.65.

TABLE1 DESCRIPTIVE STATISTICS OF THE BASIC CHARACTERISTICS OF THE QUESTIONNAIRE SAMPLE

Features	Content	Sample number	percentage	Cumulative percentage
Incumbent post	R & D Center Supervisor	48	37.5%	37.5%
	Team or project leader	63	49.2%	86.7%
	Ordinary R & D personnel	17	13.3%	100.0%
Tenure of office	Below 2 years	27	21.1%	21.1%
	2-5 years	55	43.0%	64.1%
	5-10 years	36	28.1%	92.2%
	More than 10 years	10	7.8%	100.0%
Enterprise sales revenue	0-50 million yuan	31	24.2%	24.2%
	50-200million yuan	44	34.4%	58.6%
	More than 200 million yuan	53	41.4%	100.0%
R & D investment accounted for the proportion of sales revenue	3%-4%	31	24.2%	24.2%
	4%-6%	44	34.4%	58.6%
	6%-10%	28	21.9%	80.5%
	More than 10%	25	19.5%	100.0%

TABLE 2 DESCRIPTIVE STATISTICS OF VARIABLES

variable	Item	Minimum value	Maximum value	Mean value	Standard deviation
Technological innovation performance	Technological innovation performance 1	1	5	2.08	1.039
	Technological innovation performance 2	1	5	3.48	0.955
	Technological innovation performance 3	1	5	3.42	0.985
	Technological innovation performance 4	1	5	3.66	0.715
	Technological innovation performance 5	1	5	2.85	1.058
	Technological innovation performance 6	1	5	3.22	1.157
Special human capital of R & D personnel	Specific human capital 1	1	5	3.14	1.085
	Specific human capital 2	2	5	3.34	0.863
	Specific human capital 3	2	5	3.16	0.811
	Specific human capital 4	1	5	3.41	0.827
	Specific human capital 5	1	5	3.50	0.956
	Specific human capital 6	1	5	3.23	0.898
	Specific human capital 7	1	5	3.59	0.959
	Specific human capital 8	1	5	3.40	0.917
Technology uncertainty	Technology uncertainty 1	1	5	3.95	1.037
	Technology uncertainty 2	1	5	4.02	0.842
	Technology uncertainty 3	1	5	2.84	1.193
	Technology uncertainty 4	1	5	3.77	1.046
Market uncertainty	Market uncertainty 1	2	5	3.44	0.954
	Market uncertainty 2	1	5	3.40	1.037
	Market uncertainty 3	1	5	3.30	1.104
	Market uncertainty 4	1	5	3.74	1.052
Competitive uncertainty	Competitive uncertainty 1	1	5	2.94	1.121
	Competitive uncertainty 2	1	5	3.34	1.212
	Competitive uncertainty 3	1	5	3.64	1.148
	Competitive uncertainty 4	1	5	3.71	1.059
	Competitive uncertainty 5	1	5	3.49	1.204
Policy uncertainty	Policy uncertainty 1	1	5	3.47	1.079
	Policy uncertainty 2	1	5	3.12	1.168
	Policy uncertainty 3	1	5	3.53	1.034
	Policy uncertainty 4	1	5	3.32	1.049

1) Data Collection and Descriptive Statistics

a) Data Collection

Questionnaires had been distributed to high-tech R & D staffs. There are three main forms: corporate site distribution, third-party online survey and email survey. The enterprise site distribution, primarily through participating in a number of high-tech R & D personnel related conference to field release, and therefore the higher the recovery rate and the valid rate, a total of 89 questionnaires were returned 72 questionnaires, of which 65 valid questionnaires. Third-party online research, mainly through the micro-channel and web survey questionnaire in two ways, 55 questionnaires were received, of which 34 valid questionnaires. Issued a total of 100 questionnaires by mail paid out were returned 43 questionnaires, the number of valid questionnaires to 29 parts. A total of 170 questionnaires in three ways copies of 128 valid questionnaires. The valid rate was 75.3%.

b) Descriptive Statistics

Descriptive statistics for each variable are given in Table 2

In Table 2, there are six variables and each variable includes some items. Most standard deviation is nearby 1, which shows the dispersion degree is reasonable.

2) Reliability and Validity

In this study, the validity and reliability was tested separately by exploratory factor analysis and Cronbach α coefficients (Cronbach's α).

Prior to factor analysis, depending on KMO value of the sample data and Bartlett spherical te it should determine whether the sample is suitable for factor analysis. The KMO value is 0.826 R & D risk, greater than 0.8, and the Bartlett statistic is significantly different from 0 and can pass through 0.05 of significant Bartlett spherical test, which is suitable for factor analysis. Technological innovation performance KMO is 0.833, greater than 0.8, and the Bartlett statistic significantly different from 0. R & D personnel KMO mediating variables specific human capital value is 0.816, greater than 0.8, and the Bartlett statistic significantly different from 0, by the Bartlett spherical test. Therefore, R&D specific human capital has been further analyzed with the method of factor analysis. Concrete results in the following table:

TABLE3 RELIABILITY AND VALIDITY OF THE SCALE VARIABLE INSPECTION

Scale	Latent Variables	Observation variable	Factor load	Cronbach's alpha	
R & D risks	Technology uncertainty	eES1	0.723	0.838	0.894
		eES2	0.812	0.849	
		eES3	0.793	0.857	
		eES4	0.772	0.844	
	Market uncertainty	eTR1	0.764	0.857	0.876
		eTR2	0.749	0.864	
		eTR3	0.827	0.848	
		eTR4	0.653	0.857	
	Competitive uncertainty	eRC1	0.839	0.840	0.867
		eRC2	0.795	0.844	
		eRC3	0.817	0.861	
		eRC4	0.826	0.853	
	Policy uncertainty	eJP1	0.767	0.831	0.857
		eJP2	0.842	0.854	
		eJP3	0.623	0.843	
		eJP4	0.774	0.834	
Technological innovation performance	Technological innovation performance	iES1	0.782	0.923	0.924
		iES2	0.726	0.878	
		iES3	0.691	0.912	
		iES4	0.655	0.892	
		iES5	0.670	0.928	
		iES6	0.809	0.907	
R & D special human capital	Special human capital	TD1	0.652	0.843	0.830
		TD2	0.706	0.809	
		TD3	0.759	0.804	
		TD4	0.699	0.813	
		TD5	0.717	0.800	
		TD6	0.764	0.803	
		TD7	0.704	0.810	
		TD8	0.657	0.801	

The results showed that each item and dimension of each question Cronbach's alpha coefficients were greater than 0.65, some reach 0.9, which indicates that the study scale has good reliability. The confirmatory factor analysis showed that the factor loadings were above 0.6, and some questions of the load factor of 0.9, which indicates that the scale has good validity.

3) Simple correlation analysis of the variables

This study will testify the relationship between variables and regression analysis depends on a certain degree of correlation between the variable. Therefore, with Pearson's correlation analysis method, this paper has calculated simple correlation coefficient between the explained variables, the explanatory variables, intermediary variables and control variables. The results are shown in Table 4.

4) Regression Analysis

This study variables have been multicollinearity tested and heteroscedasticity tested, in which model variables VIF index is greater than 0 and less than 10, indicating that the present study regression model explanatory variables do not exist multicollinearity. The present study conducted using a

TABLE 4 CORRELATION ANALYSIS AMONG VARIABLES

	1	2	3	4	5	6	7	8
Control variable								
1 sales revenue	1.000							
2 R & D investment ratio	0.012	1.000						
Explanatory variable								
3 Technology uncertainty	0.056	0.188	1.000					
4 Market uncertainty	-0.132	-0.127	0.302	1.000				
5 Policy uncertainty	-0.99	0.068	0.283	0 .265	1.000			
6 Competitive uncertainty	-0.001	-0.024	0.249	0.046	0.230	1.000		
Mediator variable								
7 Special human capital of R & D personnel	0.037	0.359	-0.168	-0.146	-0.103	-0.060	1.000	
Explained variable								
8 Enterprise technology innovation performance	0.114	0.270	-0.255	-0. 074*	-0.061	0.115	0.224	1.000

Means p<0.001； **Means P<0.01 ； *Means p< 0.05

TABLE 5 LEVEL REGRESSION RESULTS OF R&D SPECIFIC HUMAN CAPITAL

Variable	Standardized coefficient β	
	Model 1	Model 2
Control variable		
sales revenue	.167***	.102***
R & D investment ratio	.204***	.090***
Explanatory variable		
Technology uncertainty		-.138*
Market uncertainty		-.112***
Policy uncertainty		-.027*
Competitive uncertainty		-.061***
Model statistics		
F	9.711***	11.297***
Adj.R^2	.205	.378
ΔR^2	.205	.194

*** Means p<0.001； ** Means P<0.01 ； * Means p< 0.05

TABLE6 LEVEL REGRESSION RESULTS OF ENTERPRISE TECHNOLOGY INNOVATION PERFORMANCE

Variable	Standardized coefficient β		
	Model 1	Model 2	Model 3
Control variable			
sales revenue	.198***	.105n.s.	.078*
R & D investment ratio	.362***	.198***	.110***
Explanatory variable			
Technology uncertainty		.-225***	.-132***
Market uncertainty		.-172***	.-131*
Policy uncertainty		-.137***	-.092***
Competitive uncertainty		-.129***	-.064*
Mediator variable			
Special human capital of R & D personnel			.277***
Model statistics			
F	14.599***	13.403***	10.609***
Adj.R^2	.348	.476	.518
ΔR^2	.348	.128	.072

*** Means p<0.001； ** Means P<0.01 ； * Means p< 0.05

scatter plot heteroscedasticity judgment, scatter in the research model points are distributed randomly disorderly, indicating sample observation values correspond normality and homogeneity of variance assumption. Therefore, this study does not exist among the various regression models heteroscedasticity.

Table 5-6 is the result of technological innovation performance levels of return.

The regression results in Table 5 shows that R&D risk has a significant influence on R & D staff specific human capital, so hypothesis H2a-H2d were established. According to regression results Model 2 in Table 6, R & D risk has significant influence on technological innovation performance, so hypothesis H1a-H1d were verified.

Table 6 Model 3 added R & D personnel specific human capital as intermediary variables, and the R2 became 0.518, which has significantly increased, comparing with the model 2, indicating that R & D personnel specific human capital as mediating variables has significant explanatory role on technical innovation performance. Meanwhile, the standardized regression coefficient R & D personnel specific human capital is 0.277, which is positive, and the $p < 0.001$ level significantly, indicating its impact on innovation performance is positive, so the hypothesis H3 has been verified. In addition, after adding mediating variables, the regression coefficient of the original variables and significance have undergone significant changes as following: standardized regression coefficient of technological uncertainty in the model 2 became from -0.132 to -0.225, which indicates significant change; standardized regression coefficient of market uncertainty became from -0.172 to -0.131, and the significance level decreased from $p < 0.001$ to $p < 0.05$; standardized regression coefficient of policy uncertainty became from -0.137 to -0.092, which indicates change significantly; standardized regression coefficient of competition uncertainty became from -0.129 to -0.064 and the significance level decreased from $p < 0.001$ to $p < 0.05$. The above result shows that the R & D risk has affected partly technological innovation performance by R & D personnel specific human capital, which shows affect technological innovation performance, R & D personnel specific human capital has played intermediate role in influencing enterprise technological innovation performance.

IV. RESULT AND DISCUSSION

Based on literature review and theoretical analysis of the relationship between the R & D risk and enterprise technological innovation performance, R & D risk and R & D staff specific human capital, R&D personnel specific human capital and enterprise technological innovation performance, this research believe that R&D risk has affected enterprise technological innovation performance significantly and R & D personnel specific human capital plays as an intermediary variable.

Empirical research results show that R & D risk particularly includes technological uncertainty, market uncertainty, competition uncertainty, policy uncertainty, which has a significant negative impact on the enterprise technological innovation performance through R& D staff specific human capital. During the technology innovation development process, enterprises will face high-frequency technology upgrading complex situation, discerning and changing consumer demand, difficulty of marketing; and increasingly fierce competition. In China, high-tech enterprises research and development activities are very dependent on government policy, so uncertainty scientific policy will also bring some risks to innovation performance.

R & D risk which technological innovation enterprises have to face brings uncertainty and risk to business success. R & D risk will also affect R & D staffs enthusiasm to master specific knowledge and skills, weaken their technological innovation capacity and increase their turnover intention, which is very unfavorable for enterprises to obtain and maintain the core competitiveness. Enterprises should consider how to improve the R & D staffs specific human capital, reduce their turnover intention and improve their work ethic and enthusiasm.

Enterprises should pay more attention to investment into R & D personnel specific human capital. With effective communication, reasonable compensation plan, career planning and so on, enterprises encourage knowledge workers to accumulate more specific human capital. Meantime, enterprises also should encourage employees to improve their skills in their work through "learning by doing" with rewards and recognition efforts. Therefore，R&D staffs are willing to strengthen investment in specific human capital and improve its technical innovation capability, through which win-win mode are realized.

The main innovation of this paper is to consider the R & D risks from four dimensions, a more detailed study of the impact of R & D risks on technical innovation performance and specific human capital. While the introduction of R & D personnel dedicated human capital as Mediator, this paper has explored that the R&D risk's impact mechanism on technical innovation performance.

As to R&D risk on technological innovation performance, this paper only studied two paths "R & D risk - Enterprise Technology Innovation", "R & D risk - R & D personnel specific human capital - Enterprise Technology Innovation Performance". Future research could further explore other paths and improve the impact mechanism of R & D risk on enterprise technology innovation performance, through which one can pave the way for the risk management of research, on the other hand to enable enterprises to develop a comprehensive understanding of risk, early to guard against and reduce its impact on technological innovation performance.

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