

Research on the Relationship among Ownership Structure, R&D Investment and Innovation Performance: Based on Data Analysis of Listed Auto Companies in China

Wei Wang¹, Xianjun Li¹, Wenchao Liu²

¹Department of Automotive Engineering; State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing, P.R.China

²Department of Marketing, Yatai School of Business Administration, Jilin University of Finance and Economics, Changchun, P.R.China

Abstract--Ownership structure is the basic institutional arrangements of an enterprise and will affect its innovation strategy decision-making process, thereby affecting its innovation performance. With 20 listed auto companies and 72 auto parts companies in China as the sample, this study regards the annual R&D investment as the main factor affecting the innovation performance, the relative share proportion of state-owned, private, foreign and institutional ownership as the threshold variables and the total assets, asset-liability ratio, operating income, net income, establishment age and listed age as the control variables to establish the panel threshold measurement model. Based on the relevant data of the above companies from 2012 to 2014, it uses the STATA software to conduct threshold panel data model analysis and draws a conclusion that there is not a simple influence relationship between the R&D investment and innovation performance of China's listed auto companies, and their R&D investment and innovation performance will show a remarkable interval effect because of the differences in ownership structure. The conclusion will help some countries' state-owned enterprises to design the ownership structure in mixed ownership reform.

I. INTRODUCTION

Unlike Western countries, Chinese enterprises have many ownership structures[28], and the state-owned equity accounts for a large proportion. Under this institutional arrangement, do various ownership structures have an impact on enterprise R & D investment and innovation performance? Or what influence does it have and how great is the impact? No clear answers can be found in the existing studies. There are two ideas in the research on the factors affecting the enterprise innovation performance in the academic world: one is from the internal factors, such as R & D investment, enterprise human resources, enterprise social capital, enterprise technological capabilities, access to information resources, enterprise strategies and scale; the other is from external factors, such as inter-enterprise network structure, enterprise social networking and capacity, technical opportunities and technical system, government action and government policy. From the perspective of enterprise ownership structure, there are few research on the impact of ownership structure analysis on R & D investment and innovation performance, and such studies mainly analyze the impact of a particular type of ownership on the innovation activities or compare the efficiency differences between enterprises with different ownership structures [42]

[28][16][27]. Almost no study takes into account of the ownership structure, and most of the studies ignore the impact of the equity structure and concentration on the innovation performance. Moreover, in the diverse ownership context, what impact does enterprise R & D investment have on its innovation performance, a single positive influence relationship or a significant range effect? These questions remain unresolved. This paper starts from these issues, which has an important theoretical and practical significance to enrich the research on technological catch-up and innovation of backward enterprises.

II. LITERATURE REVIEW AND HYPOTHESIS

Enterprise innovation is a technological and economic activity involving a wide range and a complex process[23]. Innovation performance refers to the performance arising from the innovative activities implemented by an enterprise, including the efficiency and effectiveness of its innovative activities and procedural results, such as that the interaction between various factors in the innovation process can enhance its innovation capability, improve the industrial structure and internal production processes and generate new concepts. The factors affecting the enterprise innovative performance are complex and diverse.

A. The Impact of R & D Investment on Innovation Performance

R & D activities, as the main source of technological innovation, play a key role in the enterprise technological innovation process. Inadequate R & D investment is bound to affect the innovation ability of an enterprise, thereby affecting its innovation performance [41]. Scholars at home and abroad gave a great concern to the relationship between R & D investment and innovation performance, and a lot of empirical research was conducted. Most studies show that there is a significant positive correlation between enterprise R & D investment and innovation performance[34] [11] [32] [17]. On the one hand, with the increase in R & D investment, the enterprise gradually accesses to more new knowledge and new technologies, which promotes technological spillovers, improves innovation capacity and increases innovation output[36]. On the other hand, R & D investment can improve the ability of an enterprise to understand and evaluate new technology trends, promote it to

develop, learn, digest and absorb external technical knowledge, create favorable conditions for its technological innovation[3], and enhance its innovation speed [11]. However, with the deepening of the research, some scholars pointed out that the positive impact between R & D investment and innovation performance was uncertain. Scherer [34] believes that there is a significant positive impact between enterprise R & D investment and patent output, but there is a certain lag effect. Erickson & Jacobson [9] believe that R & D investment does not play a better role in improving enterprise innovation performance than other forms of investment. Yang Hutaio [39] believes that great R & D investment cannot guarantee high innovation performance and increasing the R & D investment cannot ensure that backward enterprises in technology will catch up with the leader. The study by Cao Yong *et al.* [2] shows that in some cases, an irrelevant or even negative correlation may be shown between R & D investment and innovation performance. Therefore, there are no consistent conclusions between the relationship between enterprise R & D investment and innovation performance. But in this study, we make hypothesis

H1: Enterprise R & D investment has positive influence on innovation performance

B. The Impact of Ownership Structure on Innovation Performance

Currently, scholars studied the impact of enterprise equity structure and type on enterprise innovation performance, or analyzed the impact of ownership concentration on enterprise innovation from the principal-agent theory, or focused on the impact of particular investors on enterprise innovation from a particular type of ownership.

The impact of ownership concentration on innovation is complex. On the one hand, based on the principal-agent theory, many scholars believe that the dispersion of equity will lead enterprise owners to pursue their own goals, which is not conducive to enterprise innovation. On the contrary, ownership concentration is conducive to enterprise innovation[14]. On the other hand, based on the myopic institutional theory, some scholars believe that ownership concentration will make managers pay more attention to short-term effect and reduce R & D investment, which is not conducive to enterprise innovation[30] [29]. In addition, some scholars believe that there is not a simple positive or negative relationship between ownership concentration and innovation[20] [21] [5] [6].

There are two different views on the impact of state-owned ownership on innovation. One view based on resource dependence theory believes that state-owned ownership can be regarded as an external shareholder with rich resources. They have specific resources, can bring the necessary resources for technological innovation and can help the enterprises to reduce external accidents and reduce the uncertain risks brought by systems and policies, thereby positively affecting innovation[31][38][6]. The other view

believes that, due to job vacancy and low marketization of owners, enterprises with large proportion of state-owned ownership relies on administrative protection or resource monopoly for a long time, there is a lack of innovation and entrepreneurship, and they do not have the motivation and advantages for innovation[23]. In this study, we make hypothesis

H2: There is a threshold effect when state-owned ownership impact on enterprise innovation.

The impact of institutional investors on innovation is also complex. Some scholars with myopic investors view believe that institutional investors are risk-averse, and when they are the majority shareholder, they will put pressure on management to better access to short-term profits, which is not conducive to long-term projects and innovation[14]. On the contrary to myopic investors view, some scholars believe that institutions and professional decision-makers have an advantage in information gathering and analysis, the institutions may be locked by the stocks held, and institutional ownership has a positive effect on R & D intensity[13] [19]. Some scholars believe that the institutional investors are divided into different types, and the impact of different types of investors on enterprise R & D investment is different[35] [15]. In this study, we make hypothesis

H3: There is a threshold effect when institutional investors ownership impact on enterprise innovation.

There is no consistent answer about the impact of private capital on innovation. Scholars often compare the private capital with the state-owned capital while studying the impact of private capital on enterprise innovation. Three results were obtained: first, private enterprises are more innovative; second, state-owned enterprises are more innovative; third, the result depends on the specific conditions[22]. The reason why private enterprises are more innovative is that private enterprises face more intense market competition, the R & D investment of private enterprises is higher than that of state-owned enterprises, and the technological innovation efficiency of private enterprises is higher than that of state-owned enterprises[7][26]. Therefore, private ownership is more conducive to innovation[37]. The reason why the state-owned enterprises are more innovative is that state-owned enterprises have more abundant resources and R&D investment capital[33], and state-owned monopoly enterprises have a greater incentive to invest in R&D[4][21]. The view that the result depends on the specific conditions recommends making an overall consideration of product type, innovation size, innovative technology and other factors[18]. In this study, we make hypothesis

H4: There is a threshold effect when private capital ownership impact on enterprise innovation.

The positive impact of foreign ownership on innovation was recognized by scholars. Scholars believe that the foreign investors not only provide financial contribution to domestic

enterprises, but also bring technical and management expertise and resources, which is particularly important in enterprises with transition economies[8][10][6][5]. Studies suggest that there are three reasons for the positive impact of foreign ownership on innovation[6]: first, a certain technical competitive advantage is required for the foreign capital of multinational companies to be invested on the core business of the domestic market. Therefore, foreign-funded enterprises have the advantage to improve the technological and innovation capability of domestic enterprises. Second, for the common good, foreign partners will encourage and help domestic enterprises to increase R & D efforts and improve innovation performance through the transfer of advanced technology resources. Third, foreign investors will encourage domestic partners to invest more in technical development by regulating their equity. In this study, we make hypothesis

H5: There is a threshold effect when foreign ownership impact on enterprise innovation.

From the above studies, it can be seen that from ownership concentration or a particular type of ownership, there is not a simple positive effect or a negative effect between ownership on enterprise innovation performance and the impact is complex. However, the nature and structure of enterprise ownership fundamentally determines the enterprise resource configuration mode, governance structure and a series of other institutional arrangements and have a profound impact on the technological innovation behaviors and innovation performance of enterprises[37]. This requires further empirical research to test the association between ownership structure and R & D investment and enterprise innovation performance in the transition economies.

III. SELECTION OF VARIABLES

To test the relationship among ownership structure, R & D investment and innovation performance, three variables were established to measure the ownership structure, R & D investment, innovation performance and some control variables.

A. Selection of Independent Variables

In this paper, independent variables mainly include ownership structure and enterprise R & D investment. First, the ownership structure is divided into four categories: state-owned, private, foreign and institutional ownership. For the sample enterprises, this study suggests that the top 10 shareholders of a company have the biggest impact on its innovation performance decisions. Therefore, the top 10 shareholders are classified according to the ownership type and the proportion of each ownership type is calculated. Then, the relative proportion of state-owned equity, private equity, foreign equity and institutional equity is taken as the threshold explanatory variables to examine the impact of the mixed ownership structure on innovation performance. Secondly, the core explanatory variable is R & D investment.

The annual R & D investment of each company is taken as the basis.

B. Selection of Dependent Variables

In this paper, the dependent variable is the enterprise innovation performance. In the empirical research on enterprise innovation performance, many scholars directly use the number of patents applied by an enterprise as the indicator to measure its innovation performance. Although patents do not absolutely represent the innovation level of an enterprise, enterprise patent indicators have versatility, consistency, availability and other advantages. Many scholars believe that the number of patents is a very appropriate and reliable proxy variable to measure the innovation performance of an enterprise[40][23]. Moreover, R & D investment has a role in promoting patent output. Patents are the main outputs of enterprise R & D activities. Therefore, this paper uses the annual increase of the number of patents of listed auto companies to measure the innovation performance.

C. Selection of Control Variables

Selection of control variables is critical to more accurately calculate the impact of ownership structure on innovation performance. Combined with the relevant studies by previous scholars, this paper regards the establishment age, listed age, size (total assets), asset-liability ratio, operating income and net income of enterprises as the control variables. First, control the enterprise age, because the enterprise age is one of the important factors affecting enterprise innovation and R & D activities. Secondly, control enterprise size. The previous studies found that in the background of the emerging economies, the relationship between enterprise size and enterprise capacity was uncertain due to underdeveloped system. In addition, indicators such as asset-liability ratio, operating income and net profit of enterprises are closely linked with the direct R & D investment and innovation output of enterprises. In this study, data of the above indicators can be obtained from the basic database and annual reports of listed companies.

IV. MODEL SPECIFICATION AND ESTIMATION METHODS

Based on the above theoretical analysis, there is a nonlinear relationship between enterprise R & D investment and innovation performance because of differences in ownership structure, and a range effect is showed. To avoid the deviation brought artificial division of ownership range, the threshold panel model developed by Hansen [12] was used to divide ownership range based on the characteristics of the data itself, thereby studying the relationship between R & D investment and enterprise innovation performance in different ownership proportion range. With ownership structure as the threshold variable, the panel threshold regression model between R & D investment and enterprise innovation

performance was established in accordance with the panel threshold analysis method first proposed by Hansen [12] and then developed by Lian Yujun, Cheng Jian [25] and Zheng Lilin [43]. Next the single threshold model was set first, and then it was extended to multi-threshold model.

A. Setting and Test of Single Threshold Panel Model

The single threshold model is set as follows:

$$y_i = \alpha_i + \beta_0 \theta_{it} + \beta_1 x_{it} I(s_{it} \leq \lambda) + \beta_2 x_{it} I(s_{it} > \lambda) + \varepsilon_{it} \quad (1)$$

Wherein, *i* represents enterprise; *t* represents time; *y* represents the explanatory variable enterprise innovation performance; *x* represents the core explanatory variable enterprise R & D investment; θ_{it} represents a group of control variables with a significant impact on innovation performance, including total assets, asset-liability ratio, annual operating income, net profit, establishment age and listed age; and *s_i* represents the threshold variable. In this paper, it represents the proportion of investor shares. λ represents the threshold to be estimated. *I*(·) represents the indicative function. When $s_i \leq \lambda$, *I*=1; otherwise, *I*=0, namely, when the threshold variable exceeds the threshold λ , the role of the relevant explanatory variables in the range is interpreted as that the explanatory variables have undergone mechanism conversion. Model estimation uses the panel fixed effect model approach to calculate the average value, thereby eliminating the individual fixed effect value α_i . Then grid search is carried out on the threshold variable, and OLS least square sense is used to solve the residual square and the least threshold estimate $s(\lambda) \hat{\lambda}$, namely, $\hat{\lambda} = \arg_{\lambda} \min(\lambda)$.

Then, F statistics ($F_1 = (s_0 - s_1(\hat{\lambda})) / \hat{\sigma}^2$) is constructed to determine whether the threshold effect is remarkable. Hansen recommends using the “Bootstrap” method to obtain its asymptotic distribution, thereby calculating the p value based on likelihood ratio test. If the p value is small enough, reject the null hypothesis, indicating the presence of at least one threshold.

B. Setting and Test of Multi-threshold Panel Model

If F_1 is rejected, continue to discuss whether the model has two or more thresholds. Assuming that there are two thresholds, the specific setting form is as follows:

$$y_i = \alpha_i + \beta_0 \theta_{it} + \beta_1 x_{it} I(s_{it} \leq \lambda_1) + \beta_2 x_{it} I(\lambda_1 < s_{it} \leq \lambda_2) + \beta_3 x_{it} I(s_{it} > \lambda_2) + \varepsilon_{it} \quad (2)$$

Model estimation uses the method introduced by Bai and Perron [1]: First fix the estimated value obtained by the single threshold model $\hat{\lambda}_1$, and then use the grid search method again to determine the second threshold value $\hat{\lambda}_2$, obtaining the

minimum residual sum of squares $s'_1(\lambda_2)$. Then fix the second threshold value $\hat{\lambda}'_2$. In turn, correct the first threshold value $\hat{\lambda}_1$, obtain the corrected first threshold value $\hat{\lambda}'_1$ with the minimum residual sum of squares $s'_1(\lambda_2)$.

Then construct the F statistics ($F_2 = (s_1(\hat{\lambda}'_1) - s'_2(\hat{\lambda}'_2)) / \hat{\sigma}^2$) according to the principles of the single threshold to determine whether the second threshold value is significant. If the null hypothesis is refused, there are at least two thresholds. Then by analogy, extend the model setting and test form until accepting the null hypothesis. The hypothesis testing of multi-threshold model is similar to single threshold model. Therefore, it will be covered again here.

V. SAMPLES AND DATA

A. Data of Ownership Structure

The study takes 20 listed auto companies and 72 auto parts companies in China as the sample. Auto companies were chosen because in China, the auto industry is not just a pillar industry; otherwise, it is a strategic pillar industry. In terms of technology, the auto industry is a complex industry involving innovation in electronics, new materials, vehicle networking, new energy and other fields. Currently, China's auto industry does not have a unified ownership structure and a mixed ownership pattern has formed. From the vehicle industry, all of the Sino-foreign joint venture, China-China joint venture and listed companies under state-owned groups adopt the mixed ownership pattern. From the ownership of the parts industry, it is dominated by the private capital, but many private holding listed companies and restructured parts enterprises under state-owned auto parts groups adopt the mixed ownership pattern. The ownership includes the mixing of state-owned capita and collective capital and the mixing of private capital, individual capital and foreign capital. The research on the association between mixed ownership structure, R&D investment and enterprise innovation performance with the auto industry as the representative is representative. In terms of ownership structure data, according to the basic information and annual reports of listed companies published on the website of Shanghai Stock Exchange and Shenzhen Stock Exchange, the researchers made a detailed inquiry of the top 10 shareholders and their share proportion in the sample enterprises from 2012 to 2014. The shareholders were classified in accordance with the state-owned, private, foreign and institutional capital, and in accordance with the four categories, the total of share proportion was calculated as the data of ownership structure.

B. Data of R & D Investment

According to the annual reports of listed companies published on the website of Shanghai Stock Exchange and Shenzhen Stock Exchange, the researchers made a detailed inquiry of the R & D investment of 92 sample auto companies from 2012 to 2014 and aggregated and unified the

measurement units.

C. Data of Patent Number

The study queried the patent number of the above 20 listed auto companies and 72 auto parts companies in China from 2011 to 2014 and classified the patents into four categories, namely, invention publicity, invention authorization, utility model and design patent. In the specific statistical process, the annual number of invention publicity, invention authorization, utility model and design patent of the listed auto companies were calculated.

D. Corporate Information and Financial Data

According to the annual reports of listed companies published on the website of Shanghai Stock Exchange and Shenzhen Stock Exchange, the researchers made a detailed inquiry of the annual total assets, total liabilities, operating income, net profit, establishment age and listed age of the sample enterprises and calculated the asset-liability ratio. At the same time, they queried the basic information and time to market and obtained the establishment age and listed age.

VI. EMPIRICAL ANALYSIS

A. Sample Descriptive Statistics

The STATA12.0 software was used to make descriptive statistical analysis on the research sample. The results are shown in Table 1. Table 1 shows the defining method of proxy variables and basic descriptive statistics in model (1).

Because the ownership structure is composed of the state-owned, private, institutional and foreign ownership and different forms of ownership will have different impact on R & D investment and innovation performance, it is necessary to conduct panel threshold analysis on ownership respectively. The STATA12.0 software was used in this study, and `xtthres` `xttr_graph` command developed by Lian Yujun [25] was combined in specific panel threshold analysis.

B. Panel Threshold Analysis of Ownership Structure

1) Threshold Effect Bootstrap Test

The proportion of state-owned equity, private equity, foreign equity and institutional equity was used as the threshold variable to establish the threshold analysis model. Because the number of thresholds cannot be predetermined, the pattern of model cannot be determined in advance. Model (2) was estimated on the assumptions of no threshold, one threshold and two thresholds, and the F statistic and the P value obtained with the Bootstrap approach is shown in Table 2.

From Table 2, it can be seen that if the state-owned equity is taken as the threshold variable, the effect of single threshold and double threshold is very significant and the corresponding bootstrap P value is 0.000, while the effect of triple threshold is not significant, and the bootstrap p value is 0.110. Therefore, double threshold model should be used in analysis if the state-owned equity is regarded as the threshold variable. If the private equity is regarded as the threshold variable, the effect of single threshold, double threshold and triple threshold is significant at the level of 1%, 5% and 10%, and the corresponding bootstrap P values are 0.003, 0.027 and 0.077 respectively. Therefore, the triple threshold model should be used in analysis if the private equity is taken as the threshold variable. If foreign equity is regarded as the threshold variable, the effect of single threshold is very significant and the corresponding bootstrap P value is 0.003, while the effect of the double threshold and triple threshold is not significant, and the corresponding bootstrap P values are 0.117 and 0.430 respectively. Therefore, single threshold model should be used in analysis if foreign equity is regarded as the threshold variable. If the institutional equity is regarded as the threshold variable, the effect of single threshold, double threshold and triple threshold is significant at the level of 1%, and the corresponding bootstrap P values are 0.000, 0.000 and 0.003 respectively. Therefore, the triple threshold model should be used in analysis if the institutional equity is taken as the threshold variable.

TABLE 1 SAMPLE DESCRIPTIVE STATISTICS (2012 ~ 2014, N = 225, T = 3 YEARS)

Variable	Description	Mean	S.D	Min.	Max.
y	Number of patents	132.1467	322.21751	1.00	2470.00
s1	State-owned equity	.3689	.40488	.00	.98
s2	Private equity	.4539	.39723	.00	1.00
s3	Foreign equity	.0655	.17198	.00	1.00
s4	Institutional equity	.1117	.12815	.00	.73
ztc	Total assets	1.41E+10	4.43E+10	3.74E+08	4.15E+11
zcfzl	Asset-liability ratio	.4674	.17984	.07	.94
yysr	Operating income	1.52E+10	6.51E+10	5.47E+07	6.30E+11
jlrr	Net profit	7.79E+08	3.02E+09	-1.66E+09	2.80E+10
yftr	R & D Investment	3.71E+08	8.52E+08	9.28E+05	6.83E+09
clnc	Establishment age	16.8800	4.36696	6.00	27.00
ssnx	Listed age	9.9644	7.02410	.00	23.00

2016 Proceedings of PICMET '16: Technology Management for Social Innovation

TABLE 2 THRESHOLD EFFECT BOOTSTRAP TESTING RESULTS

Type of ownership	Model	F	P	BS	critical value		
					1%	5%	10%
State-owned equity	One threshold	113.690***	0.000	300	51.220	12.971	4.802
	Two thresholds	182.070***	0.000	300	19.917	6.922	4.019
	Three thresholds	4.240	0.110	300	35.217	9.146	4.645
Private equity	One threshold	49.809***	0.003	300	24.534	5.370	2.194
	Two thresholds	19.727**	0.027	300	24.887	9.895	4.925
	Three thresholds	8.859*	0.077	300	36.545	12.833	6.312
Foreign equity	One threshold	48.322***	0.003	300	25.086	8.927	6.019
	Two thresholds	5.233	0.117	300	98.063	10.720	5.591
	Three thresholds	0.347	0.430	300	41.878	8.172	3.095
Institutional equity	One threshold	109.668***	0.000	300	41.643	6.234	3.737
	Two thresholds	231.097***	0.000	300	60.896	17.517	6.467
	Three thresholds	23.514***	0.003	300	19.234	8.426	5.032

Note: ① P value and critical value are based on 300 times of Bootstrap testing results;

② ***, ** and * mean significant at 1%, 5% and 10% level respectively.

2) Estimated Threshold Value and Confidence Intervals

Based on panel threshold analysis, the estimated threshold value and the corresponding 95% confidence interval when state-owned equity, private equity, foreign equity and institutional equity is taken as the threshold variable is obtained, as shown in Table 3.

From Table 3, it can be seen that two estimated threshold values are obtained when the state-owned equity is regarded as the variable, namely, 0.719 and 0.786; three estimated threshold values are obtained when the private equity is regarded as the variable, namely, 0.006, 0.088 and 0.489; one estimated threshold value is obtained when the foreign equity is regarded as the variable, namely, 0.400; and three estimated threshold values are obtained when the institutional

equity is regarded as the variable, namely, 0.067, 0.205 and 0.244. The 95% confidence intervals of various equity threshold variables are listed in Table 3.

3) Likelihood Ratio Function Graph of Threshold Analysis Model

The likelihood ratio function graph of threshold analysis model can clearly show the estimates of threshold and construction of confidence intervals. The likelihood ratio function graph of threshold analysis model when the proportion of state-owned equity, private equity, foreign equity and institutional equity is taken as the threshold variable is obtained, as shown in Figure 1 to Figure 4.

TABLE 3 ESTIMATED THRESHOLD VALUE

Type of ownership	Threshold variable	Threshold estimate	95% Conf. Interval
State-owned equity	$\hat{\lambda}_1$	0.719	[0.719, 0.719]
	$\hat{\lambda}_2$	0.786	[0.782, 0.812]
Private equity	$\hat{\lambda}_1$	0.006	[0.006, 0.719]
	$\hat{\lambda}_2$	0.088	[0.076, 0.223]
	$\hat{\lambda}_3$	0.489	[0.006, 0.489]
Foreign equity	$\hat{\lambda}_1$	0.400	[0.397, 0.403]
Institutional equity	$\hat{\lambda}_1$	0.067	[0.029, 0.067]
	$\hat{\lambda}_2$	0.205	[0.188, 0.205]
	$\hat{\lambda}_3$	0.244	[0.238, 0.255]

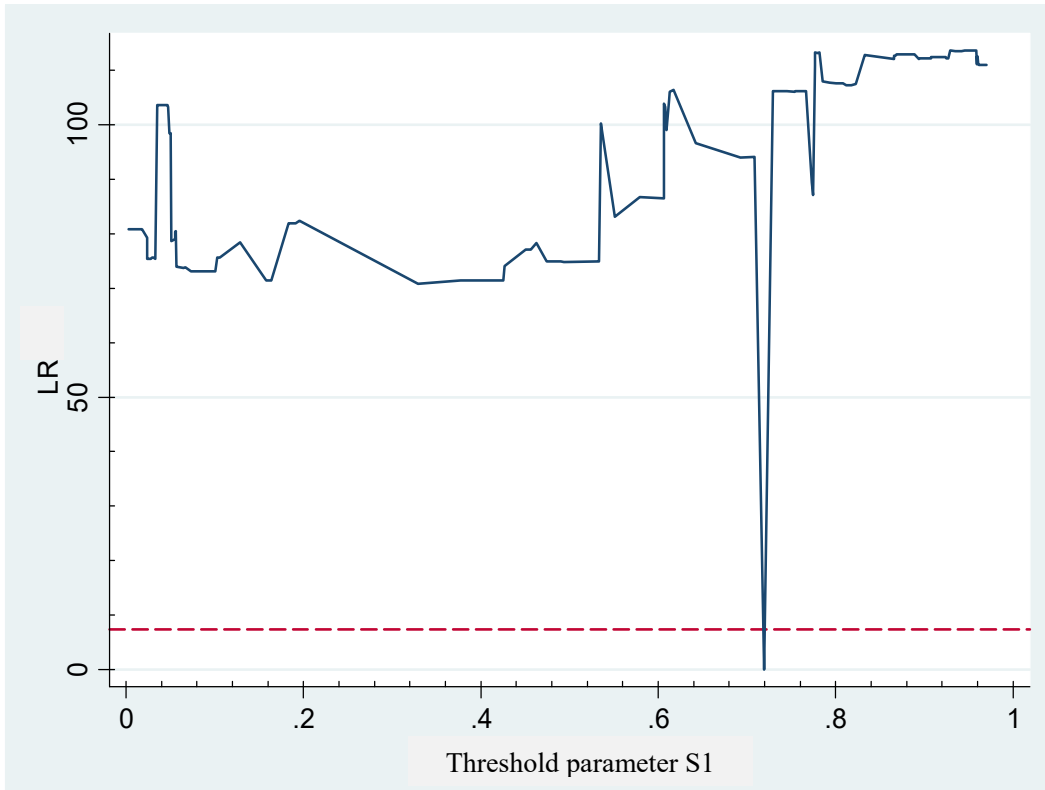


Figure 1 Likelihood ratio function graph of state-owned equity threshold analysis

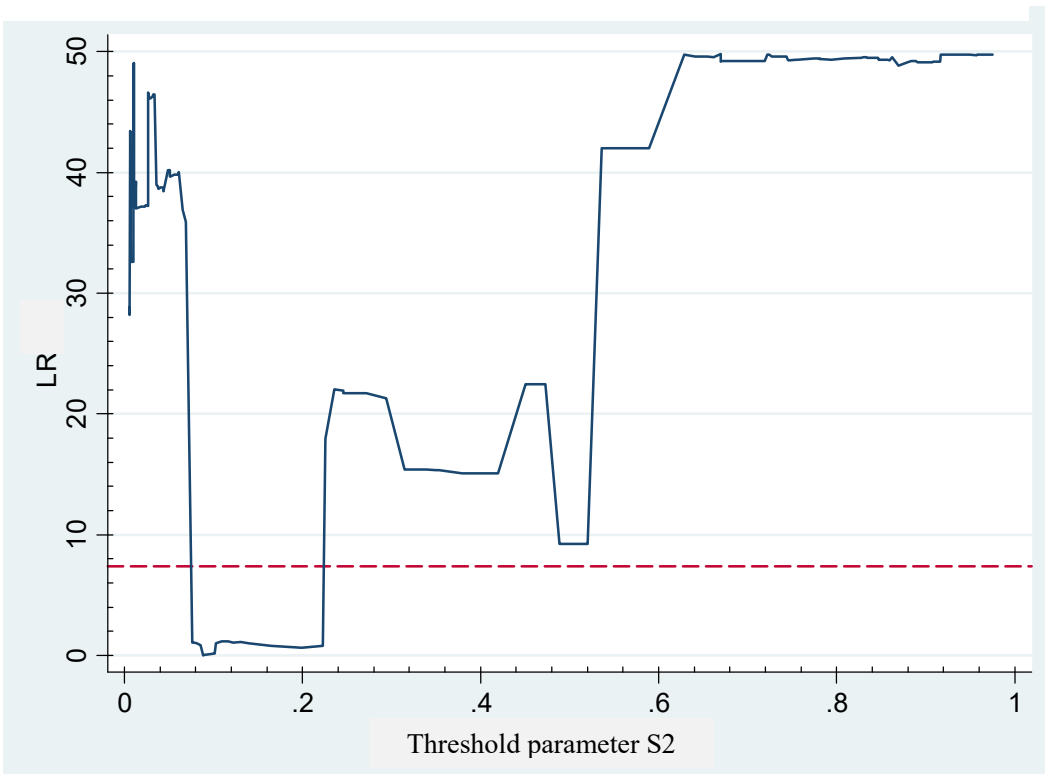


Figure 2 Likelihood ratio function graph of private equity threshold analysis

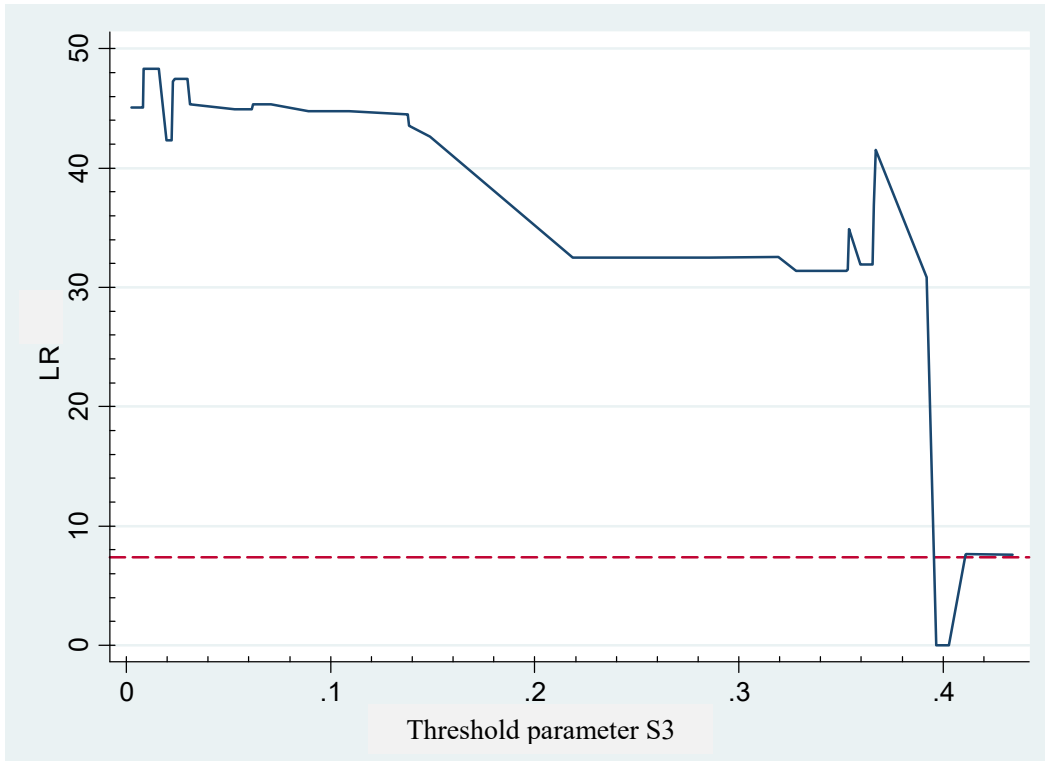


Figure 3 Likelihood ratio function graph of foreign equity threshold analysis

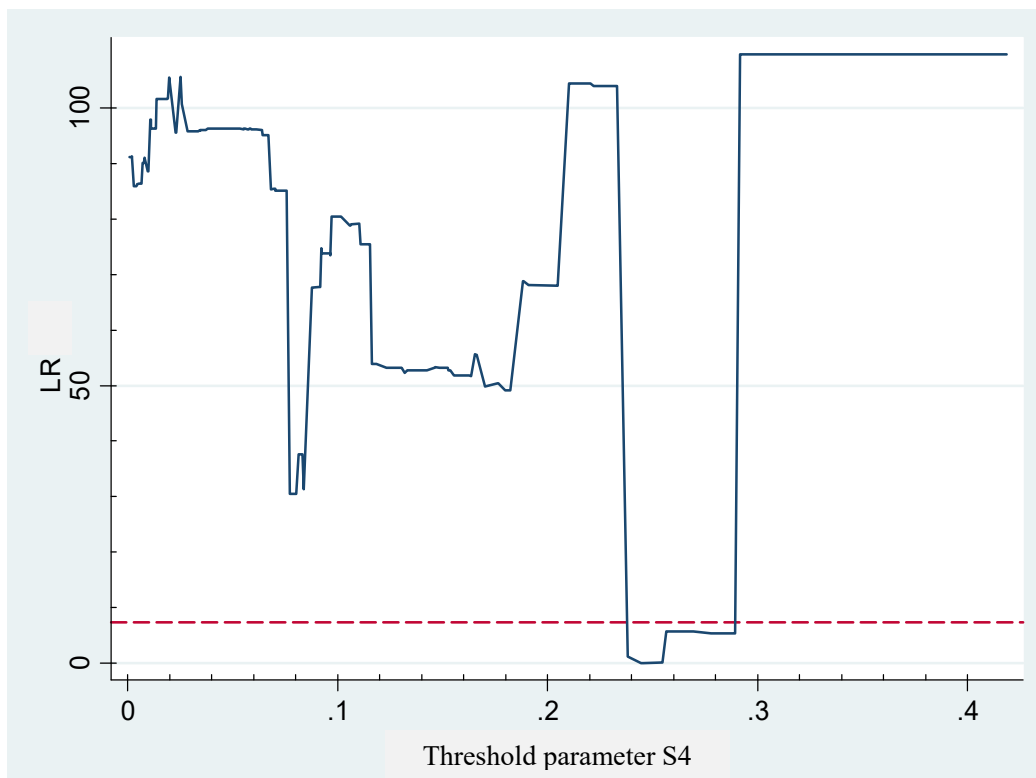


Figure 4 Likelihood ratio function graph of institutional equity threshold analysis

TABLE 4 PARAMETER ESTIMATION RESULTS OF THE MODEL

Type of ownership	Independent Variable	Coef.	t	P> t
State-owned equity	yftr_1	-2.72E-08	-0.43	0.667
	yftr_2	1.01E-06***	12.14	0.000
	yftr_3	-6.69E-08	-0.88	0.379
Private equity	yftr_1	2.11E-07**	2.29	0.024
	yftr_2	-6.36E-08	-0.64	0.525
	yftr_3	-3.70E-07***	-3.05	0.003
	yftr_4	-1.52E-07	-0.94	0.351
Foreign equity	yftr_1	1.29E-07	1.59	0.114
	yftr_2	-1.89E-07**	-2.02	0.045
	yftr_1	-5.58E-08	-1.13	0.262
Institutional equity	yftr_2	-2.26E-07***	-3.26	0.001
	yftr_3	3.76E-07***	5.82	0.000
	yftr_4	-8.65E-07***	-8.55	0.000

(4) Parameter Estimation of Threshold Analysis Model

Parameter estimation results can objectively reflect the statistical relationship between the core explanatory variable and explained variable in the threshold variable segmentation. The parameter estimation results of the model are as shown in Table 4. This paper focuses on the relationship between enterprise R & D investment and innovation performance with ownership structure as the threshold variable, so it directly shows the impact of segmented R & D investment on innovation performance, and the parameter estimation results of control variables are ignored here.

From Table 4, it can be seen that when the state-owned equity is regarded as the threshold variable and the proportion of the state-owned equity is between 71.9% and 78.6%, there is a significant positive influence relationship between enterprise R & D investment and innovation performance; and when the proportion of state-owned equity is lower than 71.9% or higher than 78.6%, there is not a significant negative influence relationship between enterprise R & D investment and innovation performance. So H2 has been supported.

When private equity is regarded as the threshold variable and the proportion of private equity is lower than 0.6%, there is a significant positive influence relationship between enterprise R & D investment and innovation performance, and when the proportion of private equity is between 8.8% and 48.9%, there is a significant negative influence relationship between enterprise R & D investment and innovation performance. While in other intervals, there is not a significant negative influence relationship between enterprise R & D investment and innovation performance. So H3 has been supported.

When foreign equity is regarded as the threshold variable and the proportion of foreign equity is higher than 40.0%, there is a significant negative influence relationship between enterprise R & D investment and innovation performance, and when the proportion of foreign equity is lower than 40.0%, there is not a significant positive influence relationship between enterprise R & D investment and innovation performance. So H4 is being supported.

When institutional equity is regarded as the threshold variable and the proportion of institutional equity is between

6.7% and 20.5%, there is a significant negative influence relationship between enterprise R & D investment and innovation performance, and when the proportion of institutional equity is between 24.4% and 20.5%, there is a significant positive influence relationship between enterprise R & D investment and innovation performance; when the proportion of institutional equity is higher than 24.4%, there is a significant negative influence relationship between enterprise R & D investment and innovation performance; and when the proportion of institutional equity is lower than 6.7%, there is not a significant negative influence relationship between enterprise R & D investment and innovation performance. So H5 has been supported.

And above all, we can see that there is not a simple positive influence relationship between enterprise R & D investment and innovation performance, so H1 has not been supported.

VII. CONCLUSIONS AND IMPLICATIONS

A. Conclusions

With the listed auto companies in China as the research object, R & D investment as the core explanatory variable, the innovation performance as the explained variable and the ownership structure as the threshold variable, this paper drew the following conclusions by panel threshold analysis:

First, this study again confirms that there is not a simple positive influence relationship between enterprise R & D investment and innovation performance. Traditionally, we generally believe that enterprise R & D investment directly affects the technological innovation. Therefore, we often simply believe that the bigger the R & D investment is, the better the innovation performance will be. However, the theoretical analysis in this paper shows that although most of the existing studies have shown that there is a significant positive correlation between enterprise R & D investment and innovation performance, the positive impact of R & D investment on innovation performance is uncertain, and in some cases, there may be an irrelevant or even negative correlation between R & D investment and innovation performance. Empirical analysis in this paper also shows that there is a significant positive or negative relationship or even

not a significant relationship between enterprise R & D investment and innovation performance because of differences in ownership structure. Therefore, this study again confirms that there is not a simple positive influence relationship between enterprise R & D investment and innovation performance.

Secondly, this study shows that there is a significant interval between R & D investment and innovation performance because of differences in ownership structure. At the institutional level, the nature and structure of corporate ownership is the most basic institutional arrangements which will affect the innovation strategy decision-making process and innovative ways, fundamentally determine the corporate resource allocation system, governance structure and a series of other important arrangements and have a profound impact on the technological innovation behaviors and innovation performance. Theoretical analysis in this paper shows that no matter what form of ownership is adopted, there is not a simple positive or negative relationship between ownership structure and innovation performance, and some relationship is complex. Empirical analysis in this paper also shows that when the proportion of state-owned equity is between 71.9% and 78.6%, there is a significant positive influence relationship between enterprise R & D investment and innovation performance; when the proportion of private equity is lower than 0.6%, there is a significant positive influence relationship between enterprise R & D investment and innovation performance, and when the proportion of private equity is between 8.8% and 48.9%, there is a significant negative influence relationship between enterprise R & D investment and innovation performance; when the proportion of foreign equity is higher than 40.0%, there is a significant negative influence relationship between enterprise R & D investment and innovation performance; when the proportion of institutional equity is between 6.7% and 20.5%, there is a significant negative influence relationship between enterprise R & D investment and innovation performance, and when the proportion of institutional equity is between 20.5% and 24.4%, there is a significant positive influence relationship between enterprise R & D investment and innovation performance. Obviously, there is a significant interval effect between R & D investment and innovation performance because of differences in ownership structure.

B. Significance

First, this study has an important theoretical significance. This paper analyzes the impact of ownership structure on enterprise R & D investment and innovation performance from the perspective of enterprise ownership structure. There are many ownership structures in Chinese enterprises. Under this institutional arrangement, different ownership structure has a different impact on enterprise R & D investment and innovation performance, and the degree of impact mainly depends on the proportion of the specific equity ownership in the enterprise. Moreover, if different ownership structures are regarded as the threshold variables, in the context of diverse

ownership, there is a significant interval effect between enterprise R&D investment and innovation performance. There is a significant positive or negative relationship or even not a significant relationship between enterprise R & D investment and innovation performance because of differences in ownership structure. It confirms that the nature and structure of enterprise ownership fundamentally determines the enterprise resource configuration mode, governance structure and a series of other institutional arrangements and have a profound impact on the technological innovation behaviors and innovation performance of enterprises. Therefore, this study has an important theoretical significance to enrich the research on technological catch-up and innovation of backward enterprises.

Secondly, this study has important practical significance. Innovation has become a common theme around the world, and enterprises in various countries are the subject of innovation. In many countries, including China, there are a variety of corporate ownership structures. This study shows that there is a significant interval effect between R & D investment and innovation performance because of differences in ownership structure. Enterprises with diverse forms of ownership structure design the ownership structure more scientifically and invest in R & D more rationally, which provides an important reference for substantially enhancing the innovation performance and is conducive for backward enterprises to better catch up with the leader in technology while participating in international competition.

C. Limitations

First, this study only selected the listed auto companies in China as the research samples. Although the research on the association between mixed ownership structure, R&D investment and enterprise innovation performance with the auto industry as the representative is representative, the sample size of listed auto enterprises in China is very limited. Initially, this study selected 20 auto companies and 72 auto parts enterprises as the research subjects, but in actual data analysis, there were a total of 75 valid samples after excluding the unsatisfactory samples and data. It has some limitations from the perspective of effective sample size.

Secondly, this study only selected the enterprise data from 2012 to 2014. Although from the requirements of panel data analysis, the enterprise data of three years meets the basic requirements, no significant changes are shown from the perspective of time series. The enterprise data from 2012 to 2014 was chosen because for the considerations of sample data availability, many listed auto companies in China were successfully listed in the past few years, and the corresponding annual reports and related data are limited. In the future, as time goes on, the annual data of the research object will be improved.

Finally, research variable data was directly used in panel threshold analysis. In the previous panel threshold research, some studies directly used the research variable data, and

some studies calculated the research variable data and conducted the logarithmic process. In general, the result may be better after calculation and logarithm process of the research variable data. This study explores the threshold effect between the ownership structure and enterprise R & D investment and innovation performance. To render the most intuitive analysis results, no special processing was conducted on the research data. Follow-up studies can try threshold analysis after special treatment of research variable data.

ACKNOWLEDGEMENTS

This research was funded by National Natural Science Foundation of China (71572093).

REFERENCES

- [1] Bai J., and P. Perron; "Estimating and Testing Linear Models with Multiple Structural Changes," *Econometrica*, Vol. 66, pp. 47-78, 1998.
- [2] Cao Yong, Fengjiao Su, and Li Zhao; "Technological Innovation Resources Input and Output Performance: An Empirical Analysis Based on the Panel Data of MIETE in China," *Science of Science and Management of S. & T*, Vol.31, pp.29-35, 2010.
- [3] Cassman B., R.Veugelers; "In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition," *Management Science*, Vol.52, pp.68-82, 2006.
- [4] Cato Susumu; "Public monopoly, mixed oligopoly and productive efficiency: a generalization," *Economics Bulletin*, Vol.12, pp.1-7, 2008.
- [5] Choi, S. B., et al.; "Does ownership structure matter for firm technological innovation performance? The case of Korean firms," *Corporate Governance: An international Review*, Vol.20, pp.267-288, 2012.
- [6] Choi, S. B., et al.; "Ownership and firm innovation in a transition economy: Evidence from China," *Research Policy*, Vol.40, pp.441-452, 2011.
- [7] Delbono Flavio and Denicolo Vincenzo; "Regulating innovative activity: The role of a public firm," *International Journal of Industrial Organization*, Vol.11, pp.35-48, 1993.
- [8] Douma, S., et al.; "Foreign and domestic ownership, business groups, and firm performance: Evidence from a large emerging market," *Strategic Management Journal*, Vol.27, pp.637-657, 2006.
- [9] Erickson G, R.Jacobson; "Gaining comparative advantage through discretionary expenditures: The returns to R&D and advertising," *Management Science*, Vol.38, pp.1264-1279, 1992.
- [10] Falk, M.; "Effects of foreign ownership on innovation activities: Empirical evidence for twelve European countries," *National Institute Economic Review*, Vol.204, pp.85-97, 2008.
- [11] Garner J.L., J. Nam, and R.E. Ottoo; "Determinants of corporate growth opportunities of emerging firms," *Journal of Economics and Business*, Vol.54, pp.73-93, 2002.
- [12] Hansen B.E.; "Threshold Effects in Non-Dynamic Panels: Estimation, Testing, and Inference," *Journal of Econometrics*, Vol.93, pp.345-368, 1999.
- [13] Hansen, G.S. & C.W.L.Hill; "Are institutional investors myopic? A time-series study of four technology-driven industries," *Strategic Management Journal*, Vol.12, pp.1-16, 1991.
- [14] Hill, C.W.L. & S.A.Snell; "External control corporate strategy and firm performance in research-intensive industries," *Strategic Management Journal*, Vol.9, pp.577-590, 1988.
- [15] Hoskisson, R.E, et al.; "Conflicting voices: The effects of institutional ownership heterogeneity and internal governance on corporate innovation strategies," *Academy of Management Journal*, Vol.45, pp.697-716, 2002.
- [16] Hu, A.G.Z, and G.H. Jefferson; "A Great Wall of Patents: What is behind China's Recent Patent Explosion?" *Journal of Development Economics*, Vol.90, pp.57-68, 2009.
- [17] Ikece, Kingsley O; "The effect of R & D investment on firm value: An examination of US manufacturing and service industries," *Production Economics*, Vol.128, pp.127-135, 2010.
- [18] Ishibashi Ikuo, and Matsumura Toshihiro; "R & D competition between public and private sectors," *European Economic Review*, Vol.50, pp.1347-1366, 2006.
- [19] Kochhar, R. & P. David; "Institutional investors and firm innovation: A test of competing hypotheses," *Strategic Management Journal*, Vol.17, pp.73-84, 1996.
- [20] Lee, P.M, and H.M. O'Neill; "Ownership structures and R&D investments of US and Japanese firms: Agency and stewardship perspectives," *Academy of Management Journal*, Vol.46, pp.212-225, 2003.
- [21] Li Chuntao and Min Song; "Innovation Activities in Chinese Manufacturing Firms: The Roles of Firm Ownership and CEO Incentives," *Economic Research Journal*, pp.55-67, May, 2010.
- [22] Li Zhanfang, Jing Xu; "A Study on Innovation Differences of Different Ownership Enterprises in China," *Reformation & Strategy*, Vol.31, pp.44-49, 2015.
- [23] Li Zheng, Yin-hong LU; "Do State-Owned Enterprises Really Lack Innovation Ability--A Comparative Analysis Based on Innovation Performance of State-owned Enterprises and Private Enterprises," *Economic Theory and Business Management*, Vol.34, pp.27-38, 2014.
- [24] Li, Y., et al.; "Ownership concentration and product innovation in Chinese firms," *Management and Organization Review*, Vol.6, pp.77-100, 2010.
- [25] Lian Yujun, and Jian Cheng; "Relationship between Capital Structure and Performance with Different Growth Opportunities," *Modern Economic Science*, Vol.28, pp.97-103, 2006.
- [26] Lin Ming Hsin, and Ogawa Hikaru; "Cost reducing incentives in a mixed duopoly market," *Economic Bulletin*, Vol.12, pp.1-6, 2005.
- [27] Lin, C.P. Lin, and F.Song; "Property Rights Protection and Corporate R&D: Evidence from China," *Journal of Development Economics*, Vol.93, pp.49-62, 2010.
- [28] Mike W. Peng, Justin Tan and Tony W. Tong; "Ownership Types and Strategic Groups in an Emerging Economy," *Journal of Management Studies*, Vol.41, pp.1105-1129, 2004.
- [29] Morck, R., et al.; "Corporate governance, economic entrenchment, and growth," *Journal of Economic Literature*, Vol.43, pp.655-720, 2005.
- [30] Ortega-Argiles, R., et al.; "Ownership structure and innovation: is there a real link?" *Annals of Regional Science*, Vol.39, pp.637-662, 2005.
- [31] Pfeffer, J. & G.R. Salancik; "The External Control of Organizations: A Resource Dependence Perspective," *New York: Harper & Row*, 1978.
- [32] Pilar B.; "Choosing among alternative technological strategies: An empirical analysis of formal sources of innovation," *Research Policy*, Vol.32, pp.693-713, 2003.
- [33] Poyago-Theotoky Joanna; "R & D competition in a mixed duopoly under uncertainty and easy imitation," *Journal of Comparative Economics*, Vol.26, pp.415-428, 1998.
- [34] Scherer F M.; "Firm sizes, market structure, opportunity and the output of patented innovations," *American Economic Review*, Vol.55, pp.1097-1125, 1965.
- [35] Sherman, H., et al.; "Institutional investor heterogeneity: implications for strategic decisions," *Corporate Governance: An international Review*, Vol.6, pp.166-173, 1998.
- [36] Wang Hongxia, Shanxing Gao; "An empirical research on the relationship between R&D investment and innovation output based on resource exploitation," *Studies in Science of Science*, Vol.26, pp.567-572, 2009.
- [37] Wu Yanbing; "Innovative Capacities of Different Ownership Enterprises," *Industrial Economics Research*, pp.53-64, Feb, 2014.
- [38] Xu, E. M, & H.Zhang; "The impact of state shares On corporate innovation strategy and performance in China," *Asia Pacific Journal of Management*, Vol.25, pp.173-187, 2008.
- [39] Yang Hutao; "More R & D investment is not equal to better innovation performance," *People's daily*, 04-02, 2008.

2016 Proceedings of PICMET '16: Technology Management for Social Innovation

- [40] Z. Acs, L. Ansclin, and A. Varga; "Patents and innovation Counts as Measures of Regional Production of New Knowledge," *Research Policy*, Vol.31, pp.1069-1085, 2002.
- [41] Zeng Deming, Ruirui Su, Jinyan Wen; "R & D Investment and Firm Innovation Performance--A Study on the Mediating Role of R & D Team's Network Structure," *Science and Technology Management Research*, pp.71-77, Sep, 2015.
- [42] Zhang, A., Y. Zhang, and R. Zhao; "A Study of the R&D Efficiency and Productivity of Chinese Firms," *Journal of Comparative Economics*, Vol.31, pp.444-464, 2003.
- [43] Zheng Lilin; "Energy Efficiency, Factor Inputs and Economic Growth--An Empirical Analysis Based on Panel Threshold Regression," *Journal of Central University of Finance and Economics*, pp.48-53, Sep, 2012.