Research on Regional Enterprise Innovation through the Innovation Survey in Haidian District, Beijing

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Abstract

Comparing with most other researches focused on the innovation theory or the countrywide innovative situation, this paper utilizes the innovation survey result—data from 638 enterprises in Haidian District, and analyzes the relationship between expenditure on different innovative activities and new product revenue from different levels through robust and quantile regressions as well as clustering analysis. The paper also extracts several internal and external factors of enterprise innovation from the survey questions, and concludes the basic ideas to improve the innovative efficiency.

Keywords: Enterprise Innovation Survey; Haidian; Innovative Input-Output

1. Introduction to the innovation survey

Independent innovation plays an extremely significant role in the process of China's development. Chinese government promulgated National Science and Technique Developing Programme for a Long Period (2006-2020) in Jan, 2006, and pointed out that the state should recognize independent innovation as a national strategy on the purpose of improving the competitiveness of China. Enterprises are the most powerful executants of innovation in a mature market economy system. Since innovation is the key point for a company to defeat other competitors in the market and to keep steady durative growth in the future, it should consist in the activities and plans of an enterprise, as well as the brains of entrepreneurs.

The existing researches on the enterprise innovation are almost based on macroeconomic growth theory and the census data in the yearbooks published by National Bureau of Statistics of China. Some authors are likely to focus on the traditional innovation theory such as Schumpter(1911) who first induced the concept of innovation, or Romer(1990) and Aghion (1992) who improved growth model with innovation theory, etc. Some authors used the data from the yearbooks to describe the factors which influence the innovative activities in China's enterprises (Zhao and Lei, 2005). There are also some authors who do researches on regional enterprise innovation relationship and diffusion through social organization theory and game theory model (Hao, 2006). These researches provided much knowledge about the general situation of enterprise innovation, research theories, study methods, and the reasonable suggestions.

However, we cannot see the substructure of innovation due to the data restriction, that is, the published census data summed the data of all the enterprises in the country, or at least in the province level, hence the microeconomic is overlooked. Unfortunately, it is the microeconomics, who tells us the power which drives a company to innovate, and the primary reason which leads to the success or failure of a company's innovative process. There were foreign researchers who ever worked on this

micro domain. For example, Jaffe (1998) used section data of 537 firms in the US in 1976 to find the elasticity between R&D expenditure and sale revenue is less than 1, and enterprise's market share has a positive effect on innovative input. Gayle (2003) used the panel data of nearly 5000 firms in America in 1976-1995 to find sale revenue and market concentration has significant positive effect on patents —the innovation output. We learn that if we can get the micro data—from the enterprises directly, and collected the information about the primary status of innovation, the flow such as input and output, the influencing factors, as well as entrepreneurs' cognition toward innovation; we might give the analysis which is more advisable.

Therefore, we make a survey which is made up of two questionnaires named Industrial Enterprise Innovation Questionnaire and Entrepreneur Questionnaire[1], and choose some corporations in Haidian district as a sample. Haidian district, which lies in the northwest of Beijing city, is a habitat center of high-tech corporations and the best universities and the top research institutions in China. This feature helps Haidian become the pioneer of innovation in all districts in China which are of the same administrative levels. We believe the science and technique development in Haidian district would be valuable experience for other areas.

The structure of the questionnaires is shown below in Table 1. From the survey we finally get the data of 638 corporations, between which some have innovative activities while some not.

Table 1 Main Indicators of the innovation Survey

Questionnaire	Concerned Aspects	Main Indicators
I. Industrial Enterprise Innovation Questionnaire	1.1 Basic Situation of the Enterprise	1.1.1 Whether an affiliated company or not 1.1.2 Level of high-technical company 1.1.3 Employee' statement 1.1.4 Amount of the technical institution
	1.2 Product Innovation	1.2.1 Whether has product innovation or not in 2004-2006 1.2.2 The contributor to the new products 1.2.3 The level of the new products 1.2.4 The kind of the product innovation
	1.3 Technique Innovation	1.3.1 Whether has technique innovation or not in 2004-2006 1.3.2 The contributor to the new techniques 1.3.3 The kind of the technique innovation
	1.4 Underway and Abeyant Innovative Activities	1.4.1 Whether have underway innovative activities 1.4.2 Whether have abeyant innovative activities 1.4.3 The time of ceasing 1.4.4 The reason for ceasing innovative activities
	1.5 Innovative Activities and the Expenditure	1.5.1 The content of innovative activities in the enterprise 1.5.2 Expenditure of the innovative activities 1.5.3 Sources of the expenditure
	1.6 Innovation Output	1.6.1 New production value and revenue 1.6.2 The proportion of different levels of new products
	1.7 Protection for the Intellectual	1.7.1 Measures to protect the Intellectual Property Rights 1.7.2 Payment for protecting the patents

[1] Both questionnaires are designed by National Bureau of Statistic of China and have the questionnaire codes: VII501&VII502.

	Property Rights	1.7.3 Payment for purchasing external techniques 1.7.4 Whether has self-brand of the main products
II. Entrepreneur Questionnaire	2.1 Basic Information about the Entrepreneurs	2.1.1 Sex 2.1.2 Age 2.1.3 Educational Degree 2.1.4 Title
	2.2 Attitude toward Innovation	2.2.1 The role that innovation plays in the subsistence and development of the corporation 2.2.2 Effects on the products 2.2.3 Effects on the techniques
	2.3 Influences On the Innovation	2.3.1 Origins of the influences 2.3.2 Depth of the influences
	2.4 Reasons For the Success of Innovation	2.4.1 The contents of the reasons 2.4.2 The extent to the influences of the reasons 2.4.3 The measures to spirit up the employees to create
	2.5 Policies On the Innovation	2.5.1 The regulations of the policies 2.5.2 The extent to the influences of the policies 2.5.3 Reasons for the invalidation
	2.6 Innovation Plans	2.6.1 Whether taking some innovative stratagems in future 2.6.2 The contents of the stratagems

2. Analysis on the different levels of enterprise innovation in Haidian

1) Introduction to the survey data and classification of the enterprises

Of those 638 enterprises, 483 have innovative activities. 72% of the 638 corporations created brand new or great improved products in 2004-2006; 51% adopted brand new or great improved producing activities; and 42% adopted brand new or great improved accessorial activities. Of the total 102,276 employees in the 638 enterprises, 35%, that is 35,428 employees, graduate from universities or graduate schools. The basic activity of innovation is internal Research & Development, which takes 97% of the 483 innovative enterprises. Training, marketing, getting equipments and software, external R&D, getting external techniques respectively take 70%, 69%, 57%, 22%, 16% of the innovative corporations. Innovative expenses in 2006 reached 5.41 billion RMB yuan. New production value in 2006 was 59.78 billion yuan. However, only 6% of the new products achieved the international innovative level, and 22% belonged to the domestic innovative level, while the other 72% are of the enterprise's innovative level. In another point of view, we find that only 66% of the 638 enterprises possess of their own brand.

In this section we partition the 638 enterprises into four levels through the innovative input and output (Table 2). In addition, we will analyze the characteristics of those different groups.

Table 2 Classification of 638 enterprises in Haidian district

Type	Description	Amount	Average Innovative Expenditure (million Yuan)	Average New Product Revenue (million Yuan)
I	Have both innovative expenditure and new production	439	9.88	138.24

II	Have innovative expenditure but no new production	39	27.50	0
III	Have new production but no innovative expenditure	2	0	11.00
IV	Have neither innovative expenditure nor new production	158	0	0

2) Analysis on the effect of the four types of innovation

First, to find the deeper relationship between enterprise innovation input and output, we choose a set of numeric variables: { $X, X_1, X_2, X_3, X_4, Y, Y_1, Y_2, Y_3$ } = {total innovative expenditure, expenditure on internal R&D[1], on external R&D[2], on getting equipments & software, on getting external techniques, total new product revenue, new product revenue from the international innovative level, from the domestic innovative level, from the enterprise's innovative level}.Obviously we have $X = X_1 + X_2 + X_3 + X_4$ and $Y = Y_1 + Y_2 + Y_3$. And Xs represent the enterprise innovative input while Ys represent the output.

Table 3 Descriptive Statistics of Type I Enterprises

		X	X1	X2	X3	X4	Y	Y1	Y2	Y3
Mean		9880.87	8379.42	808.53	523.62	169.31	138242.21	7960.62	30554.20	99727.39
Median		1684	1240	0	0	0	18135	0	1792.20	2354
Mode		100	0	0	0	0	2000	0	0	0
Std Deviation		77290.61	76663.45	6514.40	2362.78	1316.57	952085.06	61327.63	106222.36	937698.91
Skewness		19.756	20.201	11.607	7.795	14.091	17.709	11.943	6.780	18.519
Kurtosis		404.694	417.518	145.808	73.205	228.485	342.726	161.377	53.042	366.741
Maximum		1593253	1591141	94058	29894	23258	18837861	971740	1095522	18837861
Sum		4337702	3678564	354944	229869	74325	60688329	3494710.83	13413293.59	43780324.58
Quantiles	10	161	80	0	0	0	866	0	0	0
	20	419	250	0	0	0	3451	0	0	0
	25	550	366	0	0	0	5116	0	0	0
	30	726	448	0	0	0	6335	0	0	0
	40	1168	875	0	0	0	11663	0	175	394.20
	50	1684	1240	0	0	0	18135	0	1792.2000	2354
	60	2435	1940	0	0	0	28020	0	5271	6422.92
	70	3686	2934	0	30	0	45260	0	12742.5600	13160
	75	4750	3700	0	89	0	58059	0	18835.4800	20000
	80	6550	4854	0	200	0	76000	0	29601.54	28544.36
	90	13725	10411	322	720	35	162055	4528.8000	58667	89487

a. Multiple modes exist. The smallest value is shown

Because only type I enterprises have both nonzero X and Y, they are the principal part of

[1] Internal R&D indicates the R&D activities taken by the enterprises themselves.
[2] External R&D indicates the R&D activities that the enterprises commission other corporations to take.

innovation—they spend expenses on innovative activities and get new products as rewards. From the descriptive statistics (Table 3), we find that all the indicators have long and thin right tails if we draw their densities. And from the Spearman's correlations (Table 4), we also find that the total expenditure, expenditure on internal R&D, total new product revenue, new product revenue from the domestic innovative level and from the enterprise's innovative level have comparatively high correlations with each other. In contrast, expenditure on external R&D and new product revenue from the international innovative level almost do not have significant correlations with other variables.

Table 4 Spearman's Correlations between Variables of Type I Enterprises

	X	X1	X2	X3	X4	Y	Y1	Y2	Y3
X	-	0.880	0.111	0.163	0.123	0.761	0.061	0.355	0.315
X1	0.880**	-	-0.075	-0.034	-0.005	0.661	0.019	0.285	0.273
X2	0.111*	-0.075	-	0.206	0.260	0.058	0.051	0.116	-0.047
X3	0.163**	-0.034	0.206**	-	0.253	0.105	0.028	0.162	0.012
X4	0.123*	-0.005	0.260**	0.253**	-	0.074	0.010	-0.004	0.096
Y	0.761**	0.661**	0.058	0.105*	0.074	-	0.114	0.404	0.408
Y1	0.061	0.019	0.051	0.028	0.010	0.114*	-	0.162	-0.250
Y2	0.355**	0.285**	0.116*	0.162**	-0.004	0.404**	0.162**	-	-0.331
Y3	0.315**	0.273**	-0.047	0.012	0.096*	0.408**	-0.250**	-0.331**	-

* Correlation is significant at the 0.05level (2-tailed).

** Correlation is significant at the 0.01level (2-tailed)

Since the assumption of least square regression cannot be fit, we have to adopt much more stable methods to structure the model between the input and output of enterprise innovation. The four models of robust regression and quantile regression are as below (Fig.1 & postfix 1 in Table 5), whose data has been transformed by natural logarithm. From the graph we can see that the robust regression line and median regression line are almost superposed, which confirms the stability of the models. For 95% quantile regression line, its intercept is larger than median regression line while its slope is smaller than median regression line. This represents that for those enterprises that have a high input-output ratio, as the innovative expenditure adds to two times, the new product revenue only increases to 1.713 times. Thus the speed of the increase of marginal utility is slowing down. On the contrary, for 5% quantile regression line, the intercept is smaller and the slope is bigger than the median regression line. That means for those inefficient enterprises, as the innovative expenditure adds to two times, the new product revenue increases to 2.107 times, and the speed of the increase of marginal utility is quickening, which implies these enterprises should aggrandize their innovative input.

Similarly, we can build four regressions without the natural logarithm transformation (postfix 2). However, the simple univariate regression cannot reflect the influences from different kinds of innovation. Hence we use the multivariate robust and quantile regression models (postfix 3):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

Finally, to find out the influence on high level new products from the innovative activities, let

$Y' = Y_1 + Y_2$, then build four robust and quantile models with the similar form (postfix 4):

$$Y' = \beta_0' + \beta_1' X_1 + \beta_2' X_2 + \beta_3' X_3 + \beta_4' X_4 + \varepsilon'$$

The coefficient comparison between the above models is shown in Table 5.

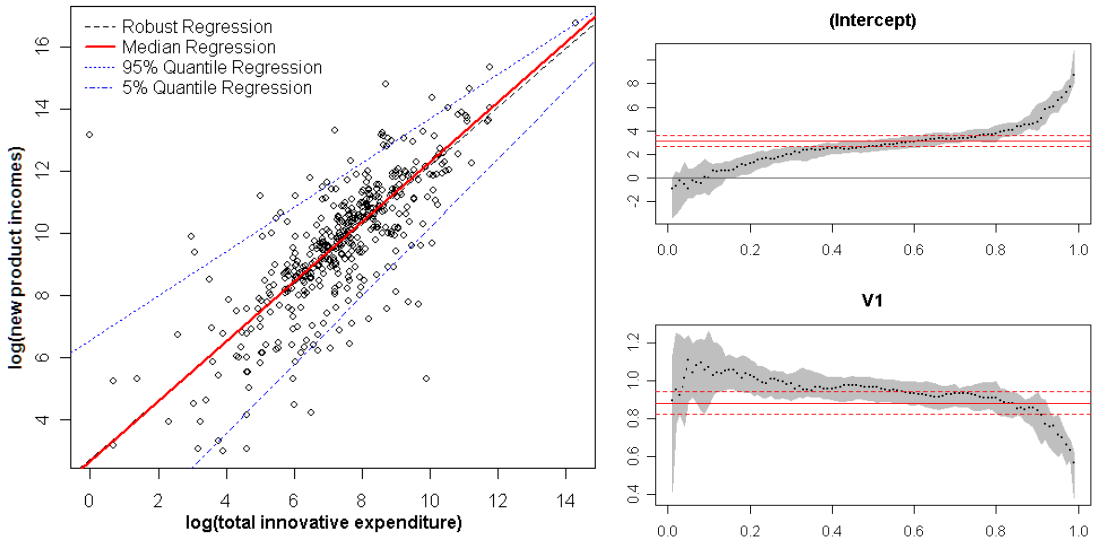

Figure 1 Robust and Quantile Regression Model with 95% Confidence Intervals

Table 5 Coefficient Estimations in Different Models

Model	Response	logarithm transformation	Intercept	X	X1	X2	X3	X4
Robust1	Y	Yes	2.53** (9.5)	0.98** (28.2)				
Median1	Y	Yes	2.67** (12. 9)	0.96** (37.3)				
5%Quantile1	Y	Yes	-0.89 (-1.5)	1.11** (11.7)				
95%Quantile1	Y	Yes	6.56** (18.9)	0.71** (29.4)				
Robust2	Y	No	2355.48** (2.6)	9.53** (52.8)				
Median2	Y	No	-435.2 (-1.1)	11.82** (46068)				
5%Quantile2	Y	No	-2870.94 (-1.0)	2.49 (0.8)				
95%Quantile2	Y	No	42466.88 (1.1)	34.78** (7.7)				
Robust3	Y	No	5633.86** (5.1)		5.18** (25.9)	19.89** (6.1)	19.19** (11.2)	10.20** (3.3)
Median3	Y	No	-151.51 (-0.3)		11.78** (186.0)	5.60** (9.2)	4.30 (0.5)	45.81 (1.0)

5%Quantile3	Y	No	-1729.6 (-0.6)		2.80 (0.6)	2.40* (2.5)	-3.47 (-0.8)	3.65 (0.6)
95%Quantile3	Y	No	38992.50 (0.5)		32.21 (1.13)	56.43 (0.6)	29.62 (0.9)	73.07** (23.0)
Robust4	Y1+Y2	No	2060.30** (8.4)		-0.03 (-1.0)	-0.06 (-0.8)	0.10 (0.7)	4.08** (5.0)
Median4	Y1+Y2	No	2022.06 (1.1)		-0.00 (-0.00)	8.38 (1.6)	0.38 (0.2)	-0.09 (-1.4)
5%Quantile4	Y1+Y2	No	NA		NA	NA	NA	NA
95%Quantile4	Y1+Y2	No	45269.73 (1.2)		14.27 (0.9)	19.12** (24.7)	9.73 (0.2)	-1.95 (-0.0)

For the total new product revenue, total innovative expenditure is always a significant predictor in robust regression. In quantile regressions, median and 95% quantile models are more significant than 5% quantile model. When considering the influence on the new product revenue from the different innovative activities, robust reg. is a method which can make every estimate significant. In quantile reg., buying external techniques is much important for those high-efficiency enterprises; and external R&D has significant effect on the low-efficiency firms. As our attention turns to the high-level new product, we find the interesting changes: only expends on external techniques affect the response significantly in robust reg.; and only external R&D is significant in 95% quantile reg.

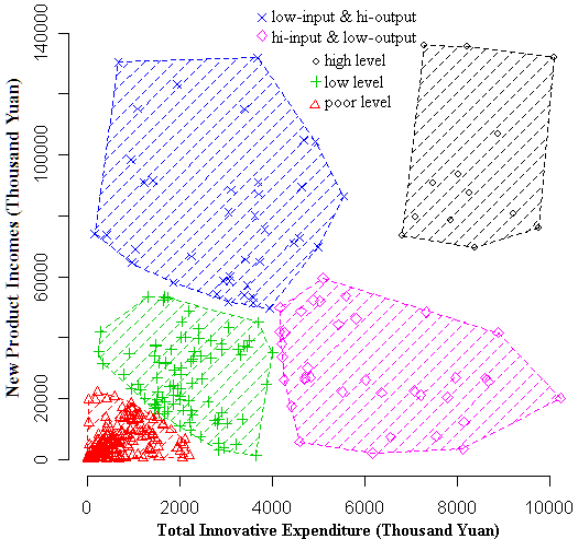

Figure 2 Clusters of Type I Enterprises by Two Variables: X,Y

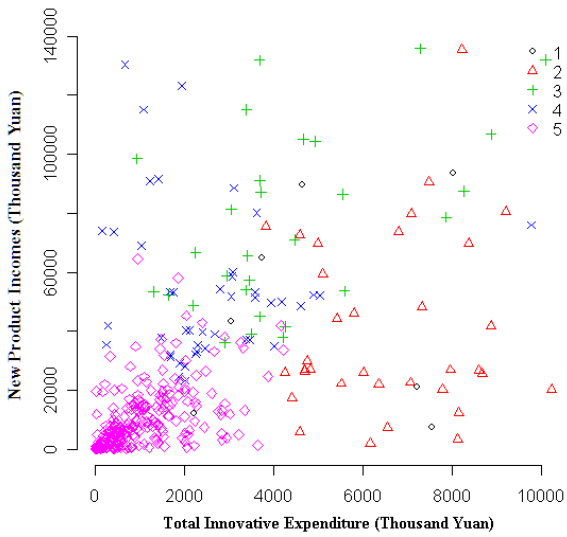

Figure 3 Clusters of Type I Enterprises by Seven Variables: X(i),Y(j)

Clustering by two variables(total innovative expenditure & total new product revenue) divides the 439 type I enterprises into 6 groups: abnormity level[1] (whose indicators are too large to sign in

[1] Actually, when clustering, we set the abnormity level for outliers because they have much longer distances with most of the other points and classifying them as others will lead to many single point groups for the outliers. And the criterion for outliers is that, let α be the distance between 25% and 75% quantiles of the total innovative expenditure and β for the distance between 25% and 75% quantiles of the total new product revenue. Any enterprise whose total innovative expenditure is larger than 75% quantile of this indicator for more than 1.5* α or whose total new product revenue is larger than 75% quantile of the indicator for more than 1.5 β is called an outlier and classified into the abnormity level.

Fig.2, 3, 4), high level, low-input & hi-output level, hi-input & low-output level, low level, and poor level. Fig.2 points the enterprises on rectangular coordinates and encloses different levels with broken lines. Clustering by seven variables ($X_1, X_2, X_3, X_4, Y_1, Y_2, Y_3$) can also divide the type I enterprises into 6 groups: the same abnormity level as above, but different five levels which are harder to name.

The first kind of enterprises marked by little circles spends more money on buying external techniques and equipments & software, and ranks the second in the series of new product revenue from international level and enterprise level. The second kind marked by triangles spend much on internal R&D but only ranks the second in the series of new product revenue from domestic level. The third kind signed by plus spends more money on equipments & software and internal R&D but pays nothing for external R&D. As a result, this kind has highest revenue from the enterprise level new products but lowest revenue from the international level. The fourth kind marked by x ploughs much money into external R&D, and gets the highest revenue from international and domestic new products as reward, but its revenue from the enterprise new products is the lowest. The fifth kind signed by diamonds spends little money on the innovative input except for external R&D, and gains little.

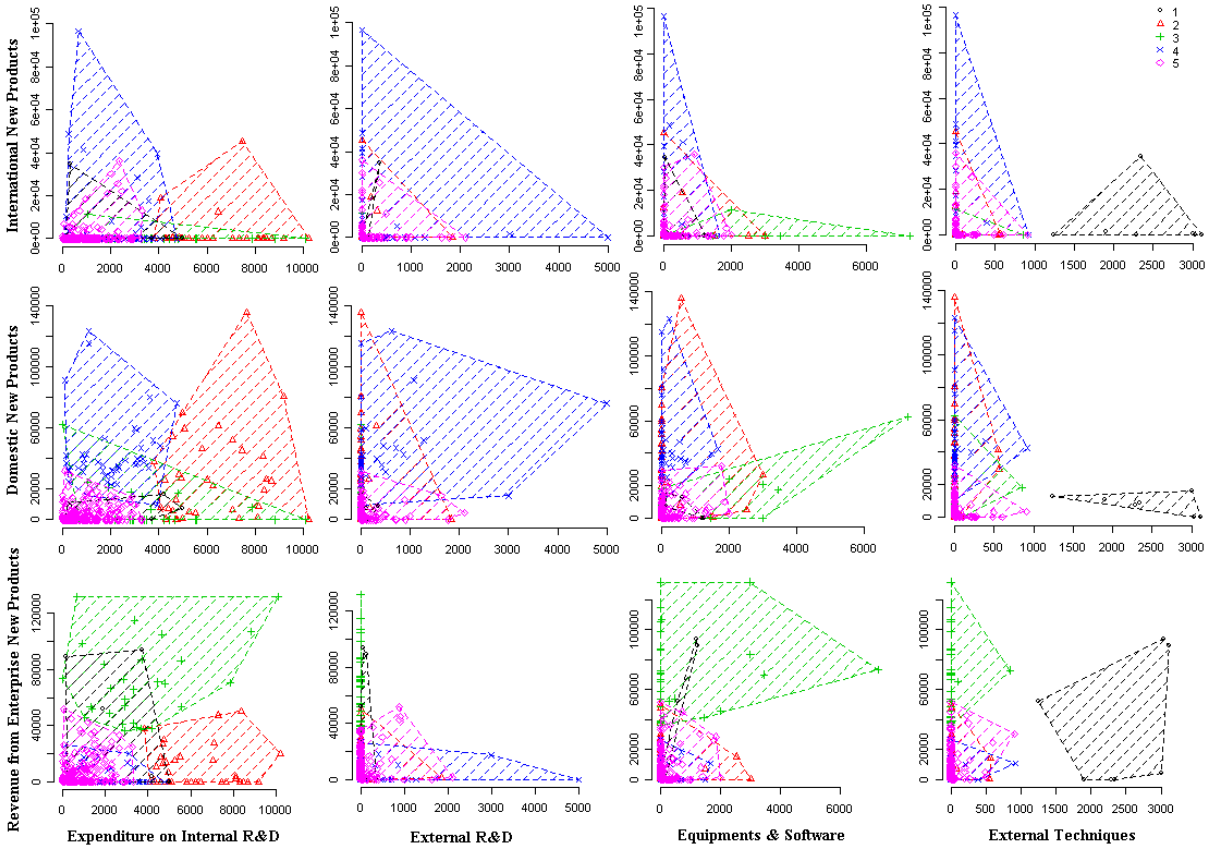

Figure 4 Innovative Expenditure and Revenue of Five Clusters of Type I Enterprises (Thousand Yuan)

From Fig. 4 we can indicate some profound features about the five clusters: for the first kind of type I enterprises, more expenditure on buying external techniques brings out more revenue from enterprise new products than international and domestic new products. For the second kind, internal R&D makes more contribution to domestic new products than international new products. For the

third kind, internal R&D contributes to enterprise new products, while getting innovative equipments and software brings benefit to both enterprise and domestic new products. For the fourth kind, the success on international new products benefits from the internal R&D more than external; but the success on domestic new products seems to benefit from both. For the fifth kind, although the general performance is not as good as other kinds, we see that its expenditure on internal R&D and buying equipments & software contributes to some revenue from international new products; and the expends on external R&D brings some revenue from enterprise new products.

Summarizing the features mentioned above, we can make some conclusions: internal R&D is essential for innovation output, especially international and domestic new products; but if an industrial firm only depends on internal R&D, the comparatively input-output efficiency will fall down. The combination of internal and external R&D will improve the input-output efficiency. The combination of internal R&D and buying equipments & software will accelerate the high-tech innovative output, that is, revenues from international and domestic new products, without the loss of input-output efficiency.

The other three types are not as important as type I when we focus on the enterprises innovation. But analysis on the effect of them, especially the type II enterprises, also supplies some conclusion: firstly, though the mean of type II enterprises' innovative expenditure is the largest of the four types, it does not mean type II enterprises spend more money on innovative input. In fact, there are only three companies whose expenditure is larger than the mean, and the median of this indicator is only 600,000 RMB Yuan. Secondly, it is a false opinion to think type II enterprises spend more money on external R&D or update the equipments which perhaps have a long cash flow period. Actually, 98% of the type II enterprises' innovative expenditure is used via internal R&D. Thirdly, it is not the type II enterprises that pay more attention on technique innovation or create more self-brand. The truth is that type II enterprises have not achieved the average level of technique innovation or self-brand property.

3. Analysis on the internal & external factors of enterprise innovation

1) Internal Factors

Background of the entrepreneurs, human resources, and funding sources are three noticeable internal factors of enterprise innovation.

There are 78% entrepreneurs in 638 who own the degree of bachelor or master, and their ages vary from 20 to 75 with the mode emerging at 40 to 45. The distribution is a little right-skewed, indicating a larger proportion of younger entrepreneurs. As for the educational levels, there are still 10% entrepreneurs with degrees of PhD. Most of their positions are general managers and board chairmen, and the proportion of female entrepreneurs is 12%. The opinions of these entrepreneurs on the influence of innovation to the survival and development of the enterprises are fairly consistent: 75.9% entrepreneurs regard innovation as important, and the other 23.7% think it is useful. For future strategies, 91.5% entrepreneurs are to adopt strategies focused on technologies, among which there are 39% planning to increase the R&D input, another 39% wishing to keep the leading position in innovation in relative fields, while 15% hoping to exceed other enterprises in innovation areas.

The numbers of employees are under 300 for most enterprises, and there is only one enterprise with more than 4000 employees. The distribution of the number of employees is heavily right-skewed, which means that the scale of most enterprises is not big. The average proportion of employees with

higher education is 47.2%. In all, enterprises with more employees tend to have lower proportion of employees with higher education; the correlation coefficient is -0.1944 and it is significant at a 0.01 level. The source of R&D on innovative products can show the capability for an enterprise to utilize internal and external human resources. From the survey we find that about 80% of the new products are created by their own employees; 7% from the cooperation with other corporations; 6% are from the cooperation with universities or institutions. The inspiration of employees' innovation is another way of developing human resources inside an enterprise. As for the policies for inspiration, the most common two policies are bonus (93.8%) and increasing salary (85.7%); other policies like options or shares are rarely adopted. The actual effects for bonus and salary are also the best, which has shown the rationality and effectiveness of these two policies for enterprises in the Haidian district.

For the source of innovation expenditure, 92.0% is from the enterprises themselves and the governmental funds take a share of 5.4%. By calculating the correlations we consider that enterprise's funds, governmental funds and financial loans are significant impacts on innovation expenditure and value of new products; see Table 6 for the correlations.

Table 6 Correlations between innovative input & output and sources of innovation expenditure

Spearman correlation coefficient	Government	Tax relief	Enterprise	Financial loans	Venture capital	Foreign	Other
Gross innovation expenditure	0.341**	0.097*	0.538**	0.172**	0.018	-0.043	0.079*
Value of new products	0.254**	0.054	0.528**	0.155**	0.035	-0.068	0.022

* Correlation is significant at the 0.05level (2-tailed).

** Correlation is significant at the 0.01level (2-tailed)

Finally we have built several models using the CART (classification and regression tree) technique to find out the most important factors determining the enterprise innovation. Conclusions from these models are: among all the internal factors that influence the enterprise innovation, with the factor of the amount of capital input excluded, the human resource for innovation is the most important factor for innovation output, no matter for output with new and advanced technologies or not. At the same time, the protection of intellectual property rights and qualities of entrepreneurs are also two important factors.

2) External Factors

The main external factors of innovation are the influence from the government policies and the driving power from the market.

The survey investigates the influence on enterprise innovation from 12 policies. We find that lightening tax burden is more favored by entrepreneurs than any other hortative policies. Counting the technique research expenditure into cost, canceling out more income taxes by the technique research expenditure, prompting the firms to cultivate and attract talented persons are several other popular policies. On contrast, the unnecessary and overelaborate formalities is the main reason that limits the effect of those popular policies. Less attraction and unknown are the primary reason for those unpopular policies.

In those entrepreneurs' opinion, the most driving power rises from exploiting new market or increasing the market shares. The following main driving powers include improving the quality of products and broadening the variety of products. There are more than half of the entrepreneurs regarding the driving powers mentioned above as important influences on innovative activities. From the answers of another question, we find that the entrepreneurs uniformly choose "Demand information from customers" as the most important source of innovation design. "Information from other enterprises in the same industry" ranks the second in this question. However, few entrepreneurs concern the information from universities, government or consulting.

At last, we build several models using the CART technique again. From these models we can conclude that the external factors that influence the enterprise innovation are from several aspects. The key point to the self-brand property as well as to the high-tech new product is the source of innovative designs; and the primary influence on the new product value is the policies about technique exploiting.

4. Conclusions and Suggestions

To summary, enterprises in Haidian district attach importance to innovation and have made great achievement. However, high concentration in several corporations indicates more companies only stay on a low innovative level.

Our suggestions involve cultivating talented person, improving their own brands, promoting the innovation of high-tech new products, enhancing the cooperation with other corporations and institutions, and increasing the input-output efficiency by suitably combining innovative activities, such as internal R&D and buying equipments & software, or internal and external R&D.

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