

Innovation Input, Innovation Output and Firm Competitiveness: An Analysis of China Pharmaceutical Industry at Firm Level

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Abstract: based on the pharmaceutical firm data from the census of National Bureau of Statistics, the relationship among innovation input, innovation output and firm competitiveness is examined. The results indicated that the relationship between innovation input and firm size follows an inverted U-shaped while the relationship between innovation output and firm size seems U-shaped. In addition, there is a significant positive correlation between innovation input and innovation output as well as between innovation output and firm competitiveness. Furthermore, comparing to other types of enterprises, the state-owned units have higher innovation inputs and the share-holding corporations limited have higher innovation outputs. When compared with the old firms, the young firms have lower innovation inputs but higher innovation outputs.

Keywords: Innovation input, Innovation output, competitiveness, Pharmaceutical firms

JEL Classification Numbers: C24, D24, L65, O33

1. Introduction

Firm competitiveness is an ability to support the sustainable development of an enterprise as well as an ability to obtain higher market share and extra profit. The higher the productivity and the higher the amount of profit or market share, the stronger competitiveness that the enterprise can have. However, the key factor to determine the enterprise's competitiveness is poorly understood, especially for firms in China. To a great extent it is innovation. The underlying fundamental is that the enterprise can obtain more superior and monopolized resources that accord with the market demand through innovation, which will lead to a better firm performance and achieve the goal of improving competitiveness. In this paper, I investigated the determinants of innovation and its contribution to the competitiveness of China's Pharmaceutical firms.

In recent years, the topic of innovation and its relationship with productivity or firm performance has been the focus of attention. There are increasing empirical studies on the link between innovation and productivity or firm performance (e.g., Griliches, 1995; Hall and Mairesse, 1995; Crepon, Duguet and Mairesse, 1998; Loof and Heshmati, 2000; 2001; Kleinknecht and Mohnen, 2002; Klomp and Van Leeuwen, 1999; van Leeuwen and Klomp, 2001; Gu and Tang, 2004; and so on). Especially, a mass of the literature uses a four-equation knowledge production function model to examine the relationship between innovation and productivity or firm performance. The model is based on that of Crepon, Duguet and Mairesse (1998), which offers a good understanding of the 'black - box' by Rosenberg

(1982). First of all, the company decides whether to innovate or not. If the company decides to innovate, what factors determine the level or the intensity of innovation input? Secondly, the innovation output is determined by the innovation input. And the innovation output is related to the firm performance or productivity. The underlying hypothesis is that the innovation input dose not influence the firm performance directly. Crepon, Duguet and Mairesse (1998) study the links between research, innovation and productivity using French manufacturing firms. Their results show that the probability of participating in research (R&D) for a firm increases with its size (number of employees), while the research capital intensity for a firm is not significant related to firm size. They also find a positive relationship between innovation output and research capital intensity as well as the innovation output and the firm productivity. Klomp and Van Leeuwen (2001) developed a simultaneous-equation model for the relationship between innovation and firm performance and found that the results of a single-equation approach are different from the results obtained from a simultaneous approach. Loof and Heshmati (2001) examined the relationship between innovation and firm performance using different data sets. The results are confusing at cross-country level. For example, firm size has a negative effect on innovation intensity in Finland, and in Norway the effect is positive, while in Sweden the effect was not significant. They also found that only in Sweden the relationship between innovation input and innovation output is significant. In the other two countries no significant relationship is found. Furthermore, the innovation output is significantly and positively related with the firm performance in Norway and Sweden, but not in Finland. In another study, Loof et al. (2002) examined sensitivity of the estimated relationship between innovation and firm performance. They found that the innovation intensity decreases with firm size in manufacturing industry, while in service industry the effect is insignificant.

In addition, the relationship between innovation and firm performance is not consistent when using the different measures of firm performance. Overall, the previous estimated results are different because of the different data sources, types of models, estimation methods and measures of firm performance or innovation. How these previous results based on foreign firms are comparable to Chinese firms are largely unknown. The objective of this paper is to investigate the determinants of innovation and the relationship between innovation and firm competitiveness in China based on the model in Crepon, Duguet and Mairesse (1998). New findings are showed and compared with results of previous studies.

The structure of the paper is as follows. The specification of empirical model and the definition of variables are described in Section 2. In section 3, some first descriptive results of the firms are presented. In section 4, the relationship between innovation and firm competitiveness will be discussed. And the estimated results from the models are presented, and the basic conclusions are drawn in section 5.

2. The Specification of Empirical Model

The empirical model used here is derived from the “chain-link model” of Kline and Rosenberg (1986) and further developed by Crepon, Duguet and Mairesse (1998). The model, referred to as CDM model for short, includes four equations. In this paper, the innovation input equations include the equation of firm’s decision to innovate and the equation of innovative investment of participated firm. The innovation output equation reveals the relationship of innovation input and innovation output. And the

competitiveness equation reveals the firm's competitiveness related to the innovation output. We also exam the feedback effect of profit on innovation input and the firm competitiveness and the feedback effect of innovation input on output.

2.1 Determines of Innovation Input

Several studies analyzed the probability of firms to innovate and assess the input of innovation once a firm decides to innovate. Generally, the total expenditures of R&D and the innovation intensity which is defined as the total of innovation expenditures divided by the total sales or the number of employees dedicated to innovation are still the most popular indicators to measure innovation input. Here, I use the R&D divided by total sales to measure the innovation input.

On the factors that influence the innovation intensity, some researches used the same set of variables explaining the probability of innovation and the intensity of innovation (Crepon et al. (1998)). Others allowed the explanatory variables partially overlapping. I follow the later one and overlap part of the explanatory variables. According to the Schumpeterian theory, Firm size (employees) and market share are all included in the two equations as explanatory variables. Firm size is defined as the number of employees and the market share is defined as the ratio of the enterprise's revenue to that of the domestic industry. In addition, if the enterprise participates in the international competition, the probability of enterprise to innovate may improve. As a result, I add a dummy variable international competition as an explanatory variable to the selection equation, indicating whether the firm participates in the international competition or not. The dummy of international competition takes the value 1 if the delivering goods value of exports is greater than 0. Furthermore, the types of firms may also influence the probability of innovate. Therefore, I add seven dummy variables to the selection equation measuring the register status of the firm. The dummy *DSO* measures whether the firm is a state-owned unit or not. It takes value 1 if the firm is a state-owned unit. The dummy variables *DCO*, *DLLC*, *DSHC*, *DPIR*, *DHM* and *DFOR* represent the Collective-owned unit, the Limited Liability Corporation, the Share-holding Corporation Ltd., the private unit, the unit with funds from Hong Kong, Macao & Taiwan and the foreign funded unit, respectively. In addition, I also add a dummy variable *OLD* measuring whether the innovation propensity of old firms is different from young firms. The young firm is the firm that entry in the market in 2006. The opposite is the old firm. If the firm is an old one, the dummy variable takes value 1.

Besides firm size, market share, the dummy variables measuring the types of firm, the dummy variable *OLD*, I also add three other explanatory variables to the innovation intensity equation. The intensity of current assets defined as the current assets divided by the employees. The predicted operation competitiveness defined as the predicted profit divided by the employees. Generally, once the firm decides to innovate, the current assets, the predicted profit of the firm obviously become the main factors that determine the amount of innovation. The more the predicted profit is, the more innovation expenditures that the firm may invest. In addition, if the firm obtains the government subsidies, it may increase the amount of innovation. As a result, I add a dummy variable *DS* measuring whether the firm has government subsidies. If it has, the dummy variable takes value 1, 0 otherwise.

From the literature review, most of the studies acknowledge that firm size is one of the most important

factors influencing the propensity of firms to innovate as well as the amount of innovation. For example, Felder et al. (1996), Vossen and Nooteboom (1996) found that the probability of a firm to innovate increase with firm size. Conditional on engaging in innovations, the innovation intensity (the R&D expenditure divided by total sales) is larger in small firms than in larger firms. The relationship between firm size and innovation intensity demonstrates a U-shaped curve. In order to test the relationship between firm size and propensity of firm to innovate and the relationship of firm size and innovation intensity, I add the squared logarithm of the number of employees to the list of explanatory variables in equation (1) and equation (2).

The specification of the model is displayed as follows:

$$G_t^* = A^0 + \beta_1^0 \lg L_t + \beta_2^0 \lg MR_t + \beta_3^0 DIM_t + \beta_4^0 (\lg L_t)^2 + \beta_5^0 X_t^0 + \varepsilon_t^0 \quad (1)$$

$$I_t^* = A^1 + \beta_1^1 \lg L_t + \beta_2^1 \lg MR_t + \beta_3^1 \lg C_t + \beta_4^1 \lg P_{t-1} + \beta_5^1 DS_t + \beta_6^1 (\lg L_t)^2 + \beta_7^1 X_t^0 + \varepsilon_t^1 \quad (2)$$

The equation (1) in the model is a selectivity equation, which describes the probability of a firm to engage in innovation. The equation (2) expresses the innovation input, where a firm decides to participate in innovation. In equation (1) and (2), G_t^* and I_t^* are all latent variables. When $G_t^* > 0$, $G_t = 1$, it indicates that the firm decide to innovate. And if $G_t = 1$, the latent innovation input I_t^* equals to the innovation input I_t , which defined as the innovation intensity. The opposite is true if $G_t^* \leq 0$. $L_t, MR_t, C_t, P_{t-1}, DIM_t, DS_t$ represent the firm size, the market share, the intensity of current assets, the predicted value of profit per employee, the dummy variable of international competition, the dummy variable of government subsidies, respectively. X_t^0 includes the dummy variables measuring the types of firms and the dummy variable *OLD*. In the model, all the variables take logarithm form except the dummy variables. And if the original value of the variable is 0, it also takes the value 0 after logarithm transformation (Mairesse, 2004). In addition, if a firm entry in the market in 2006, its predicted value takes value 0.

When only the innovation sample is used, selection bias may arise. Therefore it is in appropriate to focus only on innovative firms. Heckman's two step estimation is used to correct the selectivity bias in this paper.

2.2 Relations of Innovation Input, Output and Firm Competitiveness

The main objective of participating in innovation is to have results in innovation output, which may have direct effect on the profitability of a firm and then improve the firm competitiveness. In empirical research, innovation output is usually measured by the share of sales with product innovation, number of patents and product announcements. In particular, it seems that the share of sales with new products is a most popular indicator, which is used in recent empirical research of Loof, et al. (2001), Klomp and Van Leeuwen (1999), Kleinknecht (2000). Griliches (1980) had pointed out that the number of patents is not an appropriate indicator to measure innovation output. Kleinknecht (2000) indicated that the share of sales indicator is more robust to measure innovation output than

product announcements. Therefore, the share of sales with new products (N) is used to measure innovation output in this paper. It is specified as a function of innovation intensity (I), employment (L), physical capital K (Fixed assets per employee), predicted value of innovation intensity, predicted value of firm operation competitiveness (predicted profit per employee), market share (MR), government subsidies SUB (government subsidies per employee), export intensity(EX), a dummy variable of cost-push indicator(DCP), the inversed Mill's ratio(IMR), seven dummy variables measuring types of firms, dummy variable old measuring entry of the firm.

EX is defined as the delivering goods value of exports to sales. Crepon, et al. (1995), Kleinknecht and Oostendorp (2002) find a significant and positive relationship between innovation output and export intensity. The dummy variable DCP takes value one if the firm reduces share of sales with the selling cost of products, 0 otherwise. Especially, if the firm entries in the market in 2006, the dummy variable DCP also takes value 0, because one can not determine whether the cost decrease or increase in 2006 without data of 2005. The predicted profit per employee and the predicted innovation intensity are used to reveal how the profit in year $t-1$ influences the innovation output in year t and how the innovation input in year $t-n$ influences the innovation output in year t . In addition, in order to test the relationship between firm size and innovation output, the squared logarithm of the number of employees is added to the list of explanatory variables.

The firm competitiveness (Y) includes the market competitiveness (s) defined as the logarithm of sales per employee and the operation competitiveness (p) defined as the logarithm of profit per employee. They are expressed by the following: physical capital K (the capital per employee), employment (L), innovation output measured by the share of sales with product innovation, predicted value of profit per employee. To control for the inter-types effects, seven dummy variables measuring the types of firm are included in the equation. I also add a dummy variable OLD measuring whether the firm entry in 2006.

The innovation output and firm competitiveness models can be summarized as:

$$\lg N_t = A^2 + \beta_1^2 \lg P_{t-1} + \beta_2^2 \lg K_t + \beta_3^2 \lg L_t + \beta_4^2 \lg I_{t-1} + \beta_5^2 \lg I_{t-3} + \beta_6^2 \lg I_t + \beta_7^2 \lg EX_t \quad (3)$$

$$+ \beta_8^2 \lg MR_t + \beta_9^2 \lg SUB_t + \beta_{10}^2 DCP_t + \beta_{11}^2 IMR + \beta_{12}^2 (\lg L_t)^2 + \beta_{13}^2 X_t^0 + \varepsilon_t^2$$

$$\lg Y_t = A^3 + \beta_1^3 \lg P_{t-1} + \beta_2^3 \lg N_t + \beta_3^3 \lg K_t + \beta_4^3 \lg L_t + \beta_5^3 X_t^0 + \varepsilon_t^3 \quad (4)$$

2.3 Estimation Methods

From the literature review, we conclude that a wide range of estimation methods may be applicable. However, the estimation methods considering the selectivity and simultaneity biases are becoming more and more a standard practice. Such as, tobit, generalized tobit, probit and the Heckman Model. In the study of Crepon, Duguet and Mairesse (1998) the full information maximum likelihood method and generalized moment estimated method are used, which allow the full collection of the error terms in four equations. In the research by Klomp and Van Leeuwen (1999) the single-equation approach and the simultaneous-equation approach are applied. They estimate the simultaneous equation model with the full information maximum likelihood method. George Van Leeuwen (2002) compares the results of the static model and the results of panel-data model.

In this paper, I apply a Heckman's two-step estimation for the innovation input models (equation (1) and equation (2)) and then use 2sls to estimate the simultaneous equation model of innovation output and firm competitiveness (equation (3) and equation (4)). In equation (4), innovation output is endogenous. The only relationship of the two parts is the inversed Mill's ratio. The advantage of this method is that it avoids full correlation structure of the error terms and attains a tractable estimation procedure (Loof et al. (2001)).

3. The Data

The pharmaceutical firm data used in this paper is obtained from the census results of National Bureau of Statistics, which consist of much information including the measures of innovation, profit, among others. I selected the pharmaceutical firm data in 2006 in this work. In this subsection, I outline the procedure for selecting the data and compare the descriptive statistical results of different types of firms in 2006.

In order to improve the estimated results, some observations are eliminated. First, the firms with the number of employees less than 10 are eliminated. Secondly, the firms with innovation intensity greater than 50% and with the gross output value of industry less than 5 million Yuan are removed. There are 1357 observations corresponding to 25% of the sample. 4011 firms are selected as the sample.

Table 1: Descriptive statistics: innovative firm and non-innovative firm

variables	Innovative firm		Non-innovative firm	
	Mean	SD	Mean	SD
Number of employees (Persons)	687	1494	191	309
Total sales per employee (Thousand Yuan)	473	1265	469	743
Profit per employee (Thousand Yuan)	46.3	78	39	101
Gross output value per employee (Thousand Yuan)	509	1204	518	783
Share of sales with new products (%)	0.44	0.47	0.047	0.2
Share of export value to sales (%)	0.12	0.25	0.08	0.23
Current assets per employee (Thousand Yuan)	312	728	215	450
Physical Capital per employee (Thousand Yuan)	182	249	162	282
Share of selling cost to sales (%)	0.61	0.21	0.74	0.20
Share of government subsidies to sales (%)	0.0042	0.014	0.004	0.03
Share of sales with innovation expenditure (%)	0.025	0.037	0.005	0.02
Number of sample	591		3420	

Note: innovative firm is the firm with innovation expenditure and new product values in 2006.

The result of descriptive statistics in Table 1 shows that about 14.7% of the selected firms are the firms that have innovation expenditure and new product value in 2006. It also evidently shows that innovative firms perform better than non-innovative firms on innovation output, innovation intensity

and number of employees. But the differences are less notable for total sales per employee.

Table 2 identifies for the sample distribution of different size firms. It shows that 80% of the selected firms are small size firms. The large size firms only account for 1.57%. However, 73.2% of the large size firms are innovative firm, which is much higher than the share of innovative firms in medium size firms and small size firms.

Table 3 presents the innovation intensity, innovation output and number of employees of different types of firms. About 68.9% of selected firms are private enterprises and limited liability corporations. And the number of state-owned enterprise and collective-owned enterprise is the least, only making up 2.34% and 2% of the selected sample, respectively. In addition, the state-owned enterprise and the share-holding corporation Ltd. have higher share of innovative firms.

Table 2: Descriptive statistics: large size firm, medium size firm and small size firm

variables	Number of sample		Innovative firms		Non-innovative firms	
	Number	In %	Number	In %	Number	In %
Large size firms	56	1.4%	41	73.2%	15	26.8%
Medium size firms	668	16.7%	239	35.8%	429	64.2%
Small size firms	3287	81.9%	311	9.5%	2976	90.5%

Note: large size firm: number of employees ≥ 2000 . Medium size firm: $300 \leq$ the number of employees < 2000 . Small size firm: number of employees < 300 .

Table 3: Descriptive statistics: different types of enterprises

Types of firms	Number of sample		Innovative firms		Non-innovative firms	
	Number	In %	Number	In %	number	In %
State-owned enterprise	91	2.3%	28	30.8%	63	69.2%
Collective-owned enterprise	78	2.0%	2	2.6%	76	97.4%
Limited Liability Corporation	1119	28.8%	205	18.2%	914	81.6%
Share-holding Corporation Limited	346	8.9%	123	35.5%	223	64.5%
Private enterprise	1557	40.1%	117	7.5%	1440	92.5%
Enterprises with funds from Hong Kong, Macao & Taiwan	265	6.8%	40	15.1%	225	84.9%
Foreign funded enterprises	431	11.1%	66	15.3%	365	84.7%
Number of sample	3887	100%	581	14.9%	3306	85.1%

Note: the types of firms are defined by National Bureau of Statistics according to the register status of firm.

4. The Estimation Results

In this section, the goal is to analyze the difference of the models mentioned in the foregoing discussion and to examine the robustness of the relationship of innovation input, innovation output and firm competitiveness.

4.1 The determinants of innovation input

Table 4: the determinates of innovation input

	2.1	2.2	2.3	2.4
Probability				
	Coeff.	Coeff.	Coeff.	Coeff.
L	0.911***(0.068)	0.807***(0.069)	0.807***(0.069)	1.57***(0.355)
L2	-	-	-	-0.173**(0.079)
MR	0.2***(0.056)	0.166***(0.057)	0.166***(0.057)	0.215***(0.057)
DIM	0.061*(0.052)	0.064*(0.053)	0.06*(0.053)	0.066*(0.053)
DFOR	-	0.285**(0.141)	0.285**(0.141)	0.273*(0.141)
DHM	-	0.341**(0.149)	0.341**(0.149)	0.333**(0.149)
DPIR	-	0.07 (0.13)	0.07 (0.13)	0.051(0.130)
DSO	-	0.765***(0.189)	0.765***(0.189)	0.789***(0.189)
DSHC	-	0.446***(0.146)	0.446(0.146)	0.451***(0.146)
DCO	-	-0.47 (0.221)	-0.469 (0.221)	-0.472**(0.221)
DLLC	-	0.351***(0.131)	0.351***(0.131)	0.338***(0.131)
DOLD	-	0.241***(0.064)	0.241***(0.064)	-
Innovation intensity (I)				
P _{t-1}	-	-	0.108***(0.016)	-
L	0.468***(0.124)	0.38***(0.106)	0.354***(0.103)	0.917***(0.289)
L2	-	-	-	-0.118**(0.059)
DS	0.054(0.039)	0.055(0.039)	0.039(0.38)	0.06(0.039)
C	0.572***(0.05)	0.511***(0.053)	0.462***(0.052)	0.496***(0.053)
MR	0.495***(0.086)	0.503***(0.079)	0.399***(0.079)	0.574***(0.091)
DFOR	-	0.451***(0.146)	0.373*(0.141)	0.42***(0.148)
DHM	-	0.341**(0.155)	0.279**(0.149)	0.317**(0.156)
DPIR	-	0.173(0.139)	0.123(0.134)	0.134(0.141)
DSO	-	0.673***(0.195)	0.604***(0.188)	0.684***(0.195)
DSHC	-	0.417***(0.154)	0.333**(0.149)	0.398***(0.154)
DCO	-	-0.765*(0.273)	-0.744*(0.264)	-0.797**(0.273)
DLLC	-	0.455***(0.139)	0.385**(0.134)	0.426***(0.14)
DOLD	-	0.242***(0.079)	-0.066(0.09)	-
wald	3879***	4476***	722***	4386***

Note: Coefficients with significance to the level of 1%, 5% and 10% are marked with***, **, *. All the variables are the logarithm form with the exception with the dummy variables.

Table 4 presents the estimates for two innovation equations, the equation for the innovation probability and the equation for the innovation intensity. The difference between Model 2.1 and Model 2.2 is that Model 2.2 includes the dummy variables measuring the types of firms and the entry of the firms. Model 2.3 introduces the predicted value of profit in innovation intensity equation based on the model 2.2. And model 2.4 aims at testing the relationship between firm size and innovation intensity as well as firm size and innovation propensity.

Looking at the results of the four models, most of the variables are significant. The probability of innovate as well as the innovation intensity is highly correlated with the firm size. The larger the size

of the firm is, the higher the probability of being innovative and the higher the innovation intensity of the firm. But the firm size effects will gradually decrease. In other words, the relationship between firm size and the probability of innovation follows an inversed U-shaped, so does the relationship between firm size and the innovation intensity.

In addition to the probability of innovation, the market share and the dummy variable measuring the international competition are all positive and significant to the probability of innovation. The higher the market share is, the higher the probability of participating in innovation which is a reasonable result. In addition, violent international competition also can improve the possibility of enterprises to innovate. Furthermore, it can be seen that most of the dummy variables are significant with the exception of the estimates of the dummy variables that refer to the private enterprise and Collective-owned enterprises. Most of the firms have propensity to innovate with the exception of the Collective-owned enterprises and private enterprises. And compared with the young firms, the old firms have higher probability to innovate.

Besides the firm size, the market share (*MR*), the current assets per employee (*C*) and the predicted profit of the enterprises all have positive and significant influence on innovation input which is defined as the share of sales with innovation expenditures. Moreover, an interesting result is that the estimated coefficients of *MR* and *C* are all higher than the contribution of firm size to innovation intensity. It shows that the dummy variable *DPIR* defined as the private enterprises is insignificant and the dummy variable *DCO* defined as the Collective-owned enterprises is significantly negatively correlated to innovation input, while the other dummy variables measuring the types of firm are all significantly positively correlated to innovation input. Similar to the estimated results of the selection equation, the state-owned enterprises have higher innovation intensity than any other types of firms. Comparing to the young firms, the old firms seem to have higher innovation intensity. But the significance changes after the introduction of predicted profit. It indicates that the innovation intensity of the old firm may depend, to a great extent, on the predicted profit.

4.2 Estimates for the influence of innovation on firm competitiveness

According to the underlying rationale, innovation intensities determine the level of innovation output, which in turn are supposed to determine the firm competitiveness. In the simultaneous models the innovation output is endogenous in equation (4). Table 5 describes the estimated results of innovation input, output and operation competitiveness of enterprises. Table 6 presents the estimated results of innovation input, output and market competitiveness of enterprises. The explanatory variables are overlapping. The notable difference is the different measures of firm competitiveness.

Model 3.1 is the basic model to investigate the relationship among innovation input, output and firm competitiveness. Model 3.2 is aimed at testing the influence of predicted operation competitiveness. Model 3.3 is used to test the relationship of firm size and innovation output. The purpose of model 3.4 is to examine the impact of predicted innovation intensity on innovation output. And model 3.5 corrects for selectivity bias by using the inverse Mill's ratio in the simultaneous models. The estimated procedure and the variable setting of Model 3.6-3.10 are the same as model 3.1-3.5.

It can be seen that there is a significant positive correlation between innovation input and innovation

output as well as between innovation output and firm competitiveness after controlling for factors such as the dummy variables for the types of the firm. The relationship is relatively robust, although the estimated coefficients are distinct in different models. In model 3.1, the elasticity of innovation output with respect to innovation input is 0.325 and the elasticity of operation competitiveness with respect to innovation output is 0.316. The estimated coefficients decrease from model 3.1 to model 3.5 as well as from model 3.6 to model 3.10. It can be concluded that without considering the influence of predicted operation competitiveness and without correcting the selectivity bias may overestimate the impact of innovation inputs on innovation output as well as the innovation output on firm competitiveness.

Moreover, I find a significant positive relationship between the squared logarithm of the number of employees and the innovation output. That is to say that the innovation output seems U-shaped related to firm size (model 3.3 and model 3.8). In addition, the predicted innovation intensity is positively related to the innovation output. There is a feedback effect of innovation input on innovation output (model 3.4 and model 3.9).

Besides innovation input, the physical capital, the export intensity and the market share all have significant and positive effects on the innovation output in different models which include different sets of explanatory variables, while the government subsidies per employee has no significant effect on the innovation output. In addition, there appears to be no feedback effect from the firm competitiveness on innovation output, when taking into account of the feedback effects of innovation intensity or the selectivity bias. Furthermore, the dummy variables DLLC and DSHC are highly correlated with innovation output while the other dummy variables measuring the types of firms are insignificant. Comparing with the young firms, the old firms have lower innovation output.

In the firm competitiveness equation, the higher the innovative output is, the stronger the enterprises' operation competitiveness and market competitiveness are. It is reasonable that the employment and physical capital all have a significant and positive influence on innovation output. And compared with other types of enterprise, foreign funded firms have stronger operation competitiveness and market competitiveness, likely due to their relatively strong abilities of management and higher human capital. The significance and estimated coefficient of dummy variable *OLD* measuring the old firms is not robust due to the influence of predicted profit.

5. Conclusions

This work investigates the estimated relationship among innovation input, innovation output and firm competitiveness based on the pharmaceutical firm data from the census of National Bureau of Statistics. The following conclusions can be drawn from our empirical test. The relationship between innovation input and firm size is inverted U-shaped while the relationship between innovation output and firm size seems U-shaped. Another important finding is that there is a significant positive correlation between innovation input and innovation output as well as between innovation output and firm competitiveness after controlling for factors such as capital intensity. However, the elasticity of innovation output with respect to innovation input is in the range of 0.086-0.325. And the elasticity of firm competitiveness measures with respect to innovation output is in the range of 0.177-0.317. The distinction is due to the different sets of controlling variables, different measures of firm

competitiveness and different estimated procedures.

In addition, there is a feedback effect of innovation input on innovation output. I also find that comparing to other types of enterprises the state-owned firms have higher innovation input and the Share-holding Corporations Limited have higher innovation output. And compared with the old firms, the new firms seem to have lower innovation input but higher innovation output. Furthermore, either increasing of the market share and export intensity or reducing of the selling cost of products will be helpful to improve enterprise's innovative output. However, the government subsidies do not show significant influence on innovative output.

All of the results should provide insights into improving the competitiveness of China's pharmaceutical enterprises. First of all, in order to enhance the capability of innovation and improve the firm competitiveness, the government should encourage the rearrangement of assets inside the pharmaceutical enterprises and realize the advantage associations of the technology and resource. Secondly, encourage the independent innovation in large size firms and the cooperative innovation in medium and small size firms. Thirdly, improve the international market share under the guidance of market demand and pay attention to the industrialization of the new products.

In a word, this paper is an attempt to investigate the relationship between innovation and firm competitiveness using Chinese firm data. The next step could be the extension of the model by using different estimated procedures, considering more factors that influence the innovation such as the innovation policy or different measures of firm competitiveness such as the total factor productivity.

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Talbe5: 2SLS estimated results of innovation on operation competitiveness of enterprises

variabl	3.1	3.2	3.3	3.4	3.5
e	Coeff. (s.d.)	Coeff. (s.d.)	Coeff. (s.d.)	Coeff. (s.d.)	Coeff. (s.d.)

	The operation competitiveness (p)				
P_{t-1}	-	0.330*** (0.014)	0.342*** (0.012)	0.341***(0.014)	0.344***(0.014)
N	0.325*** (0.025)	0.128***(0.02)	0.202***(0.021)	0.09***(0.018)	0.086***(0.018)
L	0.384*** (0.052)	0.332***(0.043)	0.213***(0.04)	0.356***(0.042)	0.353***(0.042)
K	0.359*** (0.04)	0.378***(0.025)	0.234***(0.025)	0.382***(0.03)	0.383***(0.025)
DFOR	0.697*** (0.091)	0.735***(0.078)	0.298***(0.078)	0.707***(0.075)	0.707***(0.075)
DHM	0.575*** (0.096)	0.679***(0.08)	0.245***(0.087)	0.658***(0.08)	0.653***(0.08)
DPIR	0.460*** (0.073)	0.612***(0.064)	0.111(0.075)	0.587***(0.063)	0.586***(0.063)
DSO	0.01(0.137)	0.301***(0.113)	-0.132(0.11)	0.261***(0.109)	0.236***(0.111)
DSHC	0.227***(0.099)	0.389****(0.083)	-0.03(0.084)	-0.01(0.085)	0.375****(0.08)
DCO	0.632****(0.128)	0.631****(0.102)	0.161(0.115)	0.38****(0.082)	0.586****(0.1)
DLLC	0.252****(0.081)	0.436****(0.071)	0.032(0.077)	0.426****(0.07)	0.429****(0.07)
DOLD	0.155****(0.042)	-0.688****(0.054)	-0.78***(0.05)	-0.72****(0.054)	-0.724(0.054)
	Innovation output (N)				
P_{t-1}	-	0.048***(0.024)	0.037(0.024)	0.03(0.023)	0.033(0.024)
L	0.220***(0.083)	0.206***(0.084)	-1.31(0.423)	0.154*(0.083)	0.077(0.087)
L2	-	-	0.342****(0.096)	-	-
K	0.144****(0.083)	0.134****(0.049)	0.113****(0.055)	0.112***(0.047)	0.122****(0.047)
I	0.316****(0.026)	0.310****(0.026)	0.302****(0.022)	0.181****(0.032)	0.178****(0.032)
I_{t-1}	-	-	-	0.187****(0.035)	0.186****(0.035)
I_{t-3}	-	-	-	0.102****(0.036)	0.096****(0.035)
EX	0.197****(0.019)	0.195****(0.019)	0.188****(0.016)	0.196****(0.019)	0.194****(0.019)
MR	0.190****(0.032)	0.168****(0.034)	0.256****(0.081)	0.116***(0.035)	0.109****(0.035)
SUB	-0.018(0.030)	-0.02(0.029)	-0.021(0.026)	-0.04(0.029)	-0.042(0.029)
DFOR	-0.1 (0.145)	-0.127(0.145)	-0.177(0.166)	-0.122(0.142)	-0.124(0.142)
DHM	-0.1(0.158)	-0.01(0.159)	-0.052(0.176)	0.005(0.154)	-0.005(0.154)
DPIR	0.211*(0.121)	0.188(0.121)	0.132(0.144)	0.199*(0.118)	-0.206***(0.118)
DSO	0.281(0.205)	0.282(0.205)	0.225(0.224)	-0.209(0.2)	-0.056(0.208)
DSHC	0.692****(0.160)	0.669****(0.159)	0.582***(0.172)	0.62*(0.158)	0.193*(0.114)
DCO	0.001(0.175)	-0.03(0.175)	-0.106(0.233)	0.044(0.169)	0.087(0.169)
DLLC	0.408****(0.128)	0.389****(0.128)	0.352***(0.153)	0.386****(0.125)	0.375****(0.126)
DCP	3.5e-07** (1.4e-07)	3.5e-07** (1.4e-07)	5.8e-08 (1.5e-07)	3.8e-07** (1.53e-07)	1.3e-07 (2.3e-07)
DOLD	-0.04(0.062)	-0.165***(0.1084)	-0.135(0.093)	-0.232****(0.083)	-0.244****(0.083)
IMR	-	-	-	-	0.117****(0.053)
R²	0.4	0.4	0.33	0.41	0.41
F	120	108	240	104	102

Note: the value in the bracket is the std. error of the coefficient. Coefficients with significance to the level of 1%, 5% and 10% are marked with***, **, *. All the variables are the logarithm form with the exception with the dummy variables.

Talbe6: 2SLS estimated results of innovation on market competitiveness of enterprises

variable	3.6	3.7	3.8	3.9	3.10
	Coeff. (s.d.)	Coeff. (s.d.)	Coeff. (s.d.)	Coeff. (s.d.)	Coeff. (s.d.)

	The market competitiveness (S)				
P_{t-1}	-	0.082*** (0.007)	0.083*** (0.007)	0.087***(0.006)	0.082***(0.007)
N	0.269***(0.017)	0.209***(0.015)	0.209***(0.015)	0.155***(0.012)	0.185***(0.012)
L	0.405***(0.057)	0.4***(0.027)	0.401***(0.026)	0.416***(0.025)	0.397***(0.025)
K	0.103***(0.019)	0.097***(0.017)	0.098***(0.017)	0.139***(0.014)	0.133***(0.017)
DFOR	0.132***(0.05)	0.127***(0.044)	0.128***(0.043)	0.13***(0.042)	0.137***(0.04)
DHM	0.027(0.054)	0.025(0.048)	0.026(0.047)	0.065(0.045)	0.07(0.044)
DPIR	-0.002 (0.043)	0.007(0.038)	0.007(0.038)	0.017(0.038)	0.055**(0.02)
DSO	-0.213*(0.073)	-0.152**(0.064)	-0.149**(0.063)	-0.136**(0.057)	-0.14**(0.036)
DSHC	-0.126**(0.056)	-0.087*(0.049)	-0.0086*(0.048)	-0.06(0.044)	-0.073*(0.032)
DCO	0.214***(0.073)	0.167*(0.065)	0.166***(0.064)	0.121**(0.059)	0.138** (0.061)
DLLC	-0.109**(0.045)	-0.087*(0.04)	-0.087**(0.04)	-0.046(0.039)	-0.047(0.036)
DOLD	0.141*** (0.023)	-0.051*(0.269)	-0.052**(0.026)	-0.112*** (0.024)	-0.096*** (0.025)
	Innovation output (N)				
P_{t-1}	-	0.042*(0.025)	0.038(0.025)	0.02(0.024)	0.021(0.025)
L	0.158*(0.09)	0.159*(0.09)	-1.32 (0.443)	0.061(0.091)	0.037(0.095)
L2	-	-	0.344*** (0.107)	-	-
K	0.105**(0.051)	0.105**(0.05)	0.116**(0.05)	0.1*(0.057)	0.104**(0.053)
I	0.317*** (0.026)	0.312*** (0.026)	0.306*** (0.026)	0.179*** (0.026)	0.177*** (0.027)
I_{t-1}	-	-	-	0.189*** (0.029)	0.189*** (0.035)
I_{t-3}	-	-	-	0.104*** (0.028)	0.098*** (0.036)
EX	0.194*** (0.019)	0.193*** (0.019)	0.19*** (0.019)	0.193*** (0.016)	0.19*** (0.019)
MR	0.3*** (0.072)	0.257*** (0.076)	0.256*** (0.076)	0.241*** (0.079)	0.257** (0.077)
SUB	-0.017(0.030)	-0.019(0.029)	-0.022(0.029)	-0.04(0.025)	-0.043(0.03)
DFOR	-0.179(0.148)	-0.186(0.148)	-0.177(0.148)	-0.215(0.164)	-0.234(0.145)
DHM	-0.06(0.162)	-0.06(0.161)	-0.052(0.108)	-0.079(0.174)	-0.105(0.157)
DPIR	0.134(0.126)	0.131(0.125)	0.132(0.065)	0.114(0.15)	0.105(0.122)
DSO	0.233(0.103)	0.244(0.207)	0.225(0.207)	0.147(0.222)	-0.033(0.213)
DSHC	0.627*** (0.162)	0.622*** (0.162)	0.582** (0.163)	0.541** (0.171)	0.481** (0.162)
DCO	-0.081(0.18)	-0.089(0.18)	-0.106(0.181)	-0.04(0.231)	-0.012(0.174)
DLLC	0.627*** (0.162)	0.339*** (0.13)	0.352*** (0.131)	0.307** (0.152)	0.281** (0.128)
DCP	3.2e-07** (1.5e-07)	3.3e-07** (1.45e-07)	5.8e-08 (1.9e-07)	3.2e-07** (1.3e-07)	4.7e-07** (2.4e-07)
DOLD	-0.065(0.063)	-0.166** (0.083)	-0.134* (0.084)	-0.235** (0.093)	-0.25*** (0.083)
IMR	-	-	-	-	0.131*** (0.071)
R²	0.4	0.4	0.41	0.4143	0.415
F	168	159	55	55	53.87

Note: the value in the bracket is the std. error of the coefficient. Coefficients with significance to the level of 1%, 5% and 10% are marked with***, **, *, respectively. All the variables are the logarithm form with the exception with the dummy variables.