Comparison on the Impact of Two Types of R&D Funds on Innovative Outputs in the Industry-University System

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***Abstract*—Although the Government R&D Funds and Enterprise R&D Funds are crucial for the development of the industry, few studies has been done to analysis the impact of the two types of R&D funds on innovative outputs, based on the industry-university system. Using the developing Cobb-Douglas knowledge production function and the panel data on 30 provinces (Tibet is excluded for missing data) during 1996-2010 in China, this paper examines the output elasticity of the two types R&D funds in the industry-university system. We find, first, in industrial system, enterprise R&D output elasticity is greater than government R&D output elasticity, but in university system, the contribution of government investment is better than enterprise investment. Second, both of the funds have a high impact on the patent, and have a relatively low effect on the sales revenue of new products in industrial system and the number of papers in the university system. Third, government funds have a deeper influence on the innovation of university system than industrial system, enterprise funds have a greater effect on the innovation of industrial system than university system.**

***Index Terms*—industry-university system, government R&D funds, enterprise R&D funds, innovative outputs**

I. Introduction

Endogenous growth theory points out that the technological progress, which is caused by innovation, is the determinant of a country's sustained economic growth, and R&D activities is an important source of technological progress. In modern society, almost all of the major technical innovations are based on the large financial input in R&D. As the great input of R&D and the risk of knowledge spillover, it can't reach the social optimal level of R&D activities only by the market mechanism, the government intervention, at this time, is particularly important. The government usually uses some measures like the direct R&D investment or the indirect tax incentives to encourage the enterprise investment and development to realize the optimization and correct market failure [1] and [2]. As the implementation of the strategy of building an innovative country, the Chinese government has increased the investment in R&D, eased the tax policy, and also indirectly promoted the investment in R&D by the other department, but the inefficiency status between R&D input and output is always existed [3]. In order to understand the real situation, scholars begin to pay close attention to R&D investment and the influence on innovation output by investment in recent years. And as the government R&D funds and the enterprise R&D funds are the main source of R&D funds, researchers are analyzing the depth relationship between the two types of funds and their contribution to the innovation output, but so far, the scholars have not form a unified conclusion.

Some scholars point out that under the open innovation system, technology innovation will absorb more innovation elements, form multi-agent model which is composed by the innovation stakeholders [4]. Based on this theory, this paper aims to analyze the contribution of the two types of capital from a new Angle of view. As the rapid expansion of co-operative between industry and university, we put our study in the Industry-University system, and because there have different purpose between industry and university, it is necessary to distinguish the two kinds of R&D funds based on the different R&D objects to study the influence on the innovation output [5]. Based on the study, we want to make some proposals for the rational allocation of the types funding in industry-university system.

II. Literature Review

The study of R&D investment from different sources encompasses a very extensive literature. For example, Tassey suggests though there has different investment motives between the private and public sectors, when the government realizes the optimal allocation between the two departments, the country can achieve prosperity [6]. Carpon estimates the efficiency of R&D funds from various sources by using mathematical research methods [7]. Hu, examining the relationship between R&D investment of Chinese enterprise and productivity, finds that there has a significant positive relationship between private R&D investment and productivity, and the government R&D input has an indirect effect on productivity by stimulating the business investment [8]. Lichtenberg points out the government R&D funds have positive effect only when they received by the companies

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through competition, or the influence is negative [9]. David analyzes the different effect channels of the government R&D investment on the productivity by using a structured model, and based on the influence characteristic, the author separates the short- and long-term effects of government and private R&D input variables in the regression analysis [10]. In conclusion, the studies done by the foreigner mainly focus on the relationship between the two types of funds, and analysis their influence on the enterprise.

The domestic study of R&D investment mainly concentrated on the government R&D subsidies. Bai etc. find the government fund has significantly negative effects on the innovation efficiency using the stochastic frontier model [11]. Chen etc. suggest the government subsidies don't have significant impact on the enterprise's R&D efficiency through the empirical studies on the high-tech industries [12]. Xiong points out that the tax is the punishment for the enterprise innovation success, and though the direct subsidies from public can not improve the efficiency of R&D, it is useful for increasing the size of R&D activities [2]. Wang finds the government subsidies can positive incentive enterprise R&D investment, but doesn't have significant incentive on enterprise innovation [13]. Fan etc. investigate the influence of government R&D subsidies on the innovation performance of the national and regional innovation systems, the results indicate that the influence of government R&D subsidies have a significant effect on the innovation output [14]. These studies generally regard enterprise as the mainly object, research the influence of government funds on the innovation output, and the research conclusions are also different.

At the same time, some domestic scholars pay their attentions on the utility of R&D funds from different sources. For instance, Gao etc., based on the research on Chinese High-tech Industry, find that R&D funds from different sources have different preferences for different types of enterprise [3]. Cheng etc. analyze the influence of external financing on the R&D production of High-tech industry, the result shows that both government and corporate funds are significantly promote the enterprise R&D output [15].

In summary, there are some research about the impact of two types of R&D funds on the innovation output, but one gap exist, the object is always limited to the enterprise [16]. It's worth noting that funding from different objects, the main characteristics are different, and the impact on innovation output will also be different, and accompanied by the arrival of industry-university cooperation upsurge, it make sense to study the role of the two types of R&D funds in the regional industry-university system.

Therefore, this paper, based on the view of double-objects and double-funds, explores the contribution of both government and corporate R&D funds on each object, and then provides advice for the reasonably investment of government and corporate R&D funds.

III. Model and Data

A. Model

Griliches created a mathematical model to analyze the R&D investment, technology transfer and Government funding how affect productivity in 1980. And he had figured out the marginal income ratio of the three variables using the Cobb-Douglas production function [14]-[17]. On this basis, the paper builds a relational model to analysis how the R&D input affects innovation output, based on the generalized C-D production function. Model is set as follows:

$$Y = A(K^g * K^e)^{\alpha} L^{\beta} \tag{1}$$

where Y is the output of innovation; A representative of the other certainty factors that affect the output in the system; K representative of the investment in R&D, including the government R&D investment and the corporate R&D investment; L expresses the human capital investment for R&D. α and β, respectively, express the elasticity of the corresponding variable.

Basing on the type (1), we get type (2) as following:

$$\begin{aligned} \ln\ln Y_{it} &= \ln\ln A_{it} + \alpha_1 \ln\ln K_{it}^g \\ &+ \alpha_2 \ln\ln K_{it}^e + \beta \ln\ln L_{it} + \mu_{it} \end{aligned} \tag{2}$$

As mentioned above, the purpose of this paper is to explore the contribution of both government and corporate R&D funds on the innovation output of each object, basing on the view of double-objects and double-funds. So applying the formula (2) to two objects, we get:

$$\begin{aligned} \ln\ln Y_{it}^e &= \ln\ln A_{it}^e + \alpha_1^e \ln\ln K_{it}^g \\ &+ \alpha_2^e \ln\ln K_{it}^e + \beta^e \ln\ln L_{it}^e + \mu_{it}^e \end{aligned} \tag{3}$$

$$\begin{aligned} \ln\ln Y_{it}^s &= \ln\ln A_{it}^s + \alpha_1^s \ln\ln K_{it}^g \\ &+ \alpha_2^s \ln\ln K_{it}^e + \beta^s \ln\ln L_{it}^s + \mu_{it}^s \end{aligned} \tag{4}$$

In the industry-university system, the university system focuses on the academic goals, however industrial system is economic goal-oriented. So in university system we use papers that been published as a representative of the output of innovation, meanwhile we use Sales Revenue of New Products as a representative of the innovation output of industrial system. While as the number of patents is an important indicator to measure the ability of innovation [14], we use the number of patents as another representative of the innovation output for both systems. In summary, basing on the different outputs, we test the following model (5), (6), (7), (8).

$$\begin{aligned} \ln\ln Pat_{it}^e &= \ln\ln A_{it}^{e1} + \alpha_1^{e1} \ln\ln K_{it}^g \\ &+ \alpha_2^{e1} \ln\ln K_{it}^e + \beta^{e1} \ln\ln L_{it}^e + \mu_{it}^{e1} \end{aligned} \tag{5}$$

$$\begin{aligned} \ln\ln In_{it}^e &= \ln\ln A_{it}^{e2} + \alpha_1^{e2} \ln\ln K_{it}^g \\ &+ \alpha_2^{e2} \ln\ln K_{it}^e + \beta^{e2} \ln\ln L_{it}^e + \mu_{it}^{e2} \end{aligned} \tag{6}$$

$$\ln\ln Pat_{it}^{s} = \ln\ln A_{it}^{s1} + \alpha_1^{s1}\ln\ln K_{it}^{g} + \alpha_2^{s1}\ln\ln K_{it}^{e} + \beta^{s1}\ln\ln L_{it}^{s} + \mu_{it}^{s1} \quad (7)$$

$$\ln\ln Pap_{it}^{s} = \ln\ln A_{it}^{s2} + \alpha_1^{s2}\ln\ln K_{it}^{g} + \alpha_2^{s2}\ln\ln K_{it}^{e} + \beta^{s2}\ln\ln L_{it}^{s} + \mu_{it}^{s2} \quad (8)$$

where model (5), (6), respectively, test the influence of the two types of funds on Patent and Sales Revenue of New Products in the industrial system; and model (7), (8) are used to test the effect of the two types of funds on Patent and the number of papers in the university system.

B. Data

The number of patents, papers and Sales Revenue of New Products are derived from China Statistical Yearbook on Science and Technology, Assembly Statistics on Science and Technology of Colleges in China. And we use R&D Personnel full-time equivalent (person-year) to represent the labor investment for R&D, use Government Funds and Enterprises Funds in the Sources of Funds for S&T Activities to represent the capital investment. Both of the two data also comes from China Statistical Yearbook on Science and Technology. In order to ensure the timeliness of the study and taking into account the availability of data, we use the data of 15 years from 1996 to 2010 and 30 regions in China (Tibet is excluded for missing data) to analysis the problem.

IV. Empirical Study and Finding

A. Descriptive Statistical Analysis

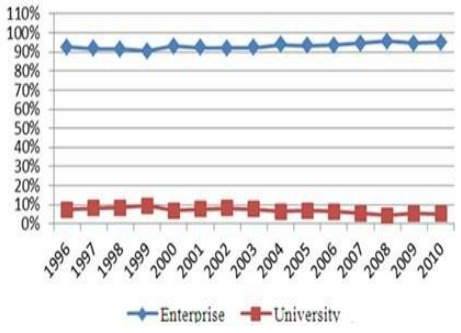

Figure 1. The allocation trends of enterprise funds in two systems.

Fig. 1 depicts the allocation trends of enterprise funds in industry and university systems, respectively. We find that in general, the trend is not significant, and the corporate financial support for universities basically maintained at below 10% of the total funds. The phenomenon shows that the financial support to university from corporate has always maintained a modest but relatively stable level.

Fig. 2 shows the allocation trends of government funds in industry and university systems, respectively. It can be found that, the distribution gap is not significant before 1999, and the enterprise gets more support than the university during this period. While after 2000, great changes take place in distribution trends, university becomes the main support one by government funds, with less funding for enterprises. Especially after 2008, the rising trends become more obvious.

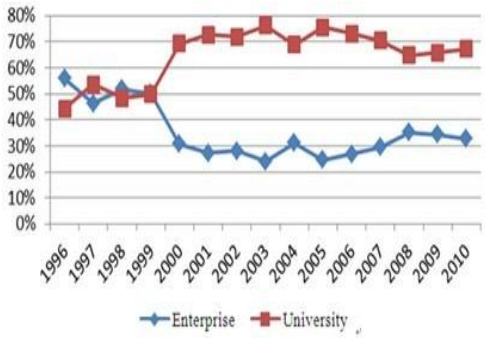

Figure 2. The allocation trends of government funds in two systems.

B. The Influence of Two Types R&D Funds on Innovation Outputs in Enterprise System

First, using the model (5) and (6), this paper analyzes the panel data of the 30 provinces in China, and then based on the results, we use the Hausman test to determine using the random effects model or fixed effects model. It is more appropriate to use fixed effects model in model (5),as the x^2=19.562490, p=0.0002 in the model (5), which means reject the null hypothesis; and it is also more appropriate to use fixed effects model in model (6), because of x^2=14.671648, p=0.0021 in model (6), the same reject the null hypothesis. The estimation results are shown in Table I, Table II.

TABLE I. The Estimation Results of the Impact of Two Types Funding on Patent in Industry System

Coefficient	$\ln A_{it}^{e1}$	α_1^{e1}	α_2^{e1}	β^{e1}
Results	-10.997348***	0.345794***	1.033756***	-0.030956
	(-14.20027)	(4.882831)	(18.04211)	(-0.531280)

NA：***represent statistical significance at the 1% level, the value of bracket on behalf of the t statistic.

TABLE II. The Estimation Results of the Impact of Two Types Funding on Sales Revenue of New Products in Industry System

Coefficient	$\ln A_{it}^{e2}$	α_1^{e2}	α_2^{e2}	β^{e2}
Results	1.770728***	0.209295***	0.918533****	-0.057882
	(3.151114)	(4.073014)	(22.09363)	(-1.369084)

NA：***represent statistical significance at the 1% level, the value of bracket on behalf of the t statistic.

According to Table I, II, government funds in industry system have significant positive effects on patent and Sales Revenue of New Products, the elastic coefficient is 0.345794 and 0.209295, respectively, and both significant at the 1% level. This means that in the enterprise, the government funding increased by 1%, enterprise patent output will grow by 0.345794%, sales revenue of new products will grow by 0.209295%. Simultaneously, enterprise funds are also significant correlations (at the 1% level) with the patent and Sales Revenue of New Products, the elastic coefficient is 1.033756 and 0.918533, respectively. However the correlation coefficients imply that the enterprise funds have a greater impact on patent and Sales Revenue of New Products than government funds, as the enterprise funding increased by 1%, enterprise patent output will grow by 1.033756%, sales revenue of new products will grow by 0.918533%.

It can be found that the labor investment doesn't have significant effects on the patent and Sales Revenue of New Products. Moreover, it can also be found the influence on the patent is always greater than the Sales Revenue of New Products either in the government funds or the enterprise funds, which indicates that there is a certain distance between the R&D results and the commercialization.

The results of Table I and II show that, both of the two types funding have the positive effects on the innovation output in the industrial system, but the contribution of government funds is less than enterprise funds. The reason may be that, first government-to-business R&D funds invested mainly exist as industry-university cooperation funds or special research projects etc., these inputs are generally stimulating enterprise increase R&D investment, and thus indirectly increase the innovation output of enterprise; Second, a considerable part of the government funds are used in development the infrastructure, those R&D results can be shared by lots of enterprises and have a distance to realize commercialization, therefore, the companies that undertake these research and development activities will not use the best equipment and personnel, but contrary, the direct purpose of enterprise R&D capital investment is to realize commercialization and get economic benefits, and the enterprise will use the best resources, which will lead to government funding contribution rate is relatively low [18]; Third, there is not established a strict regulatory mechanisms to manage the using of government-to-business R&D funding, and improper use of the government funds in the enterprise may exist, but the purpose of corporate R&D funding is clear and the use of the funds will be more reasonable and transparent, so it makes that the efficiency of government investment is lower than the enterprise funds.

C. The Effect of Two Types R&D Funds on Innovation Outputs in University System

Similar to the above methods, first, using the model (7) and (8), we analyze the panel data of the 30 provinces in China, and then based on the results, we use the Hausman test to determine using the random effects model or fixed effects model. It is more appropriate to use fixed effects model in model (7),as the x^2=52.691879, p=0.0000 model (7), which means reject the null hypothesis; and it is more appropriate to use random effects model in model (8), because of x^2=3.301427, p=0.3474 in model (8), which means cannot reject the null hypothesis. The estimation results are shown in Table III, Table IV.

TABLE III. THE ESTIMATION RESULTS OF THE IMPACT OF TWO TYPES FUNDING ON PATENT IN UNIVERSITY SYSTEM

Coefficient	$\ln A_{it}^{s1}$	α_1^{s1}	α_2^{s1}	β^{s1}
Results	-13.43691***	1.279631***	0.206363***	0.339801***
	(-15.80525)	(17.56034)	(3.014959)	(2.729159)

NA：***represent statistical significance at the 1% level, the value of bracket on behalf of the t statistic.

TABLE IV. THE ESTIMATION RESULTS OF THE IMPACT OF TWO TYPES FUNDS ON PAPERS IN UNIVERSITY SYSTEM

Coefficient	$\ln A_{it}^{s2}$	α_1^{s2}	α_2^{s2}	β^{s2}
Results	2.537251***	0.262357***	0.114344***	0.352030***
	(9.494778)	(10.94963)	(5.158708)	(8.377805)

NA：***represent statistical significance at the 1% level, the value of bracket on behalf of the t statistic.

According to Table III, IV, government funds in university system have significant positive effects on patent outputs, the elastic coefficient is 1.279631, and significant at the 1% level. This means that in the university, the government funding increased by 1%, university patent will grow by 1.279631%. Though the government investment has a positive relationship with the number of papers, the elastic coefficient is 0.262357, which is much smaller than patent's. Meanwhile, the enterprise R&D investment is also significant correlations (at the 1% level) with the number of patent and papers, the elastic coefficient is 0.206363 and 0.114344, respectively, it represents that the enterprise funding increased by 1%, university patent output will grow by 0.206363%, papers will grow by 0.114344%.

However unlike the enterprise, the labor investment in the university has significant effects on the patent and papers. Moreover, it can be found the influence on the patent is always greater than the papers either in the government funds or the enterprise funds, which indicates that patent is easier to generate than academic papers in the university system.

The results of Table III and IV show that, like the industrial system, both of the two types funding also have the positive effects on the innovation output in the university system, but the contribution of government

funds is more than enterprise funds, which is contrary to the result in industry system. The reason may be that, firstly enterprise R&D investment in universities is largely based on bilateral cooperation, and the companies are more likely in a strong position, they usually control the key resources and get more patents than universities during the cooperation. This kind of unequal reduces the contribution of enterprise capital on the university innovation output. Secondly, in the process of cooperation, the enterprise funding may be biased in favor of the pursuit of economic goals, which has a low impact on the increase of the number of papers. Thirdly, unlike the government funds, which is a continuous process supporting the development and progress of the university, enterprise may cannot have a long-term cooperation with the university, but the effect may be relatively insignificant in the short-term cooperation, so it makes the enterprise funding has a lower influence on the innovation output in university than government funding.

D. Comparison Between the Effect of Two Types R&D Funds on Innovation Outputs in Different Systems

The patent is a representative of innovation output for both industrial and university system, but Funds in different systems have different effects on the patent, as shown in Table V. Government funding in the university system has a much larger influence than industrial system. Government funds increased by 1%, the patent in the university system will increase 1.279631%, while enterprises' patent increased by only 0.345794%. Enterprise funds in the industrial system have a much larger effect than university system. The enterprise funds in industrial system growth of 1%, the patent will grow 1.033756%, while in universities the increased number is only 0.206363%.

TABLE V. THE COMPARISON OF PATENT ELASTICITY IN INDUSTRY-UNIVERSITY SYSTEM

elastic coefficient of patent	government funds	Enterprise funds
Industrial system	0.345794	1.033756
University system	1.279631	0.206363

Generally, the purpose of industrial system is to get economic benefit, and the university system is mainly academic-oriented. The contribution of different types of funds to different target-oriented system is quite different, as shown in Table VI. Government funding has a greater impact on the number of papers in universities, while has a lower effect on the sales revenue of new products in enterprises. Enterprise funds have a greater impact on sales revenue of new products, while have a smaller influence on the number of papers in university.

TABLE VI. THE COMPARISON OF OTHER OUTPUTS ELASTICITY IN INDUSTRY-UNIVERSITY SYSTEM

elastic coefficient	government funds	Enterprise funds
elasticity coefficient of sales revenue of new products in industrial system	0.209295	0.918533
elasticity coefficient of the number of papers in university system	0.262357	0.114344

In summary, government funding has a relatively high contribution to the two types innovation output of university system, enterprise funding has a high influence on the innovation output of industrial system. The results are matched with the distribution ratio of the two types funding in the two systems. On the one hand, the government investment mainly focuses on the university after 1990, and given less investment to the enterprise, on the other hand, corporate funds, supporting university R&D, also maintain at 10% or less. But it's worth noting that government funding has a positive effect on the innovation output in industrial system, and the enterprise funding also has a significant influence on the innovation output in university system. Therefore, although the contribution of the two types of funds in the two systems is difference, their roles are irreplaceable. And the performance of both types of funding in different systems needs further analysis, to find the real reason for the gap, and then the government can take the appropriate policy to improve the utilization, those may be done in the future study.

V. CONCLUSIONS AND IMPLICATIONS

The purpose of this study is to analyze the relationship of government R&D funding, enterprise R&D funding and the innovation output in industry-university system. The main conclusions are summarized below. First, in the industrial system, the contribution of enterprise funds is greater than government funds. Second, in the university system, the contribution of government investment is better than enterprise investment. Third, both of the funds have a high impact on the patent, and have a relatively low effect on the sales revenue of new products in industrial system and the number of papers in the university system. Fourth, government funds have a deeper influence on the innovation of university system than the industrial system, enterprise funds have a greater effect on the innovation of the industrial system than the university system.

We draw four implications from our findings. First, the government and industrial R&D investment are the two major capital sources of university and enterprise, both of the funds in the two systems have significant positive effect on the innovation output, despite the influence degree is different. Thus, the enterprise and university should use the two types funding more rational, increasing the innovation outputs. Second, the two systems have different R&D purpose. The university system pays more attention on the academic goals, while industrial system is more concerned about economic goals. Meanwhile the government funding is less care about the direct economic returns, however the enterprise investment is very attention to return on capital, so as a result, the government funding has a greater influence on innovation output in university system than industrial system, and enterprise funding has a greater effect on innovation output in industrial system than university system. But in the period that advocating the cooperation of industry and university, the university should enhance industry-university cooperation opportunities and

improve enterprise capital utilization efficiency. While before investment, the government should choose the enterprise strictly, such as whether creating social welfare etc., to improve the utilization efficiency of government funds. Third, with the development of multi-agent innovative models, as the main innovation subject, both the university and enterprise should make some change for the development of region and itself. More enterprises should join in the basic research, and universities should pay more attention to application research, so that both parties can actively rational use of both types of funds to contribute to society. Fourth, there is no perfect statistics of the academic achievements in enterprises and the economic success in universities, these should been strengthen in order to facilitate a more comprehensive academic research.

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