Research on Effect of Venture Capital to Technological Innovation in China

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Received 30 October 2014, www.cmnt.lv

Abstract

Basing endogenous economic growth theory and incentive-supervision theory, this paper expounds the effect of venture capital (VC) to technological innovation. Referencing the input-output method, technological innovation is thought as common goods, which can be produced during general production process. Then it chooses VC and R&D personnel as input factors, patent applications as output factor, and measures the effect of Chinese VC to technological innovation by calculating the Grey Relationship Degree (GRD). Data shows that VC's effect is stronger and stronger, even the relevant degree of government capital and technological innovation is high. By using kernel density, six pictures show that VC's distribution is disequilibrium; they reflect the main features of Chinese regional economic. Conclusions support that VC has significant effect on Chinese technological innovation. a way that using governmental invest to attractive folk and aboard is needed. Government should try to diversify the technology and investment market.

Keywords: venture capital (VC), technological innovation, Grey Relationship Degree (GRD), kernel density

1 Introduction

Many factors can influence the capacity for technological independent innovation. But the role played by finance has long been ignored. In fact, finance, especially venture capital (VC), made the US ahead in developing high tech. Alden (1975) studied the relationship between life recycle of Sci-tech enterprises and VC turns [1]. This paper is the earliest reference. Since 1991, many high-new technology enterprises had emerged that lead America to experience the longest period of sustained economic growth. VC has become a focus of the whole world. Many countries faked American experience. Then scholars researched VC and technological innovation from many theoretical aspects, such as financing constraints [2,3], game theory [4,5], exit strategy [6], organizational contract[7, 8],etc. Many researches paid more attention to VC in different countries and regions, including Germany [10], Estonia [11], Norway [12], Sweden [13], Australia [14], India [15], Silicon Valley [16], Taiwan [17], and so on. Many related results emerged. All conclusions show that VC can promote technological innovation effectively. Results of Kortum and Lerner professors indicate the contribution of VC to innovation was 3.1 times of R&D input [9]. China is experiencing an important stage of economic growth and need to drive technological innovation in a great extent. VC has developed in China for nearly forty years so far. How about its performance? What has it brought to Chinese technological innovation? Could the success of fast-growing of America be duplicated in China? This paper wants to answer this question.

Many scholars had discussed the production function of innovation [18]. This paper does it, too. But in China, the period of VC growth is short, so macro data is too little to give out a credible outcome, which we can feel in many Chinese researches before. So here it chooses another reasonable mathematical method, such as grey relationship analysis and kernel density, to overcome this limitation.

The plan of this article is as follows. Section 2 discusses the mechanism of VC to technological innovation. Section 3 presents the data and calculates the GRD of VC, government capital and R&D personnel to technological innovation. Section 4 uses kernel density to explain dynamical distribution of regional size and numbers of VC funds from 2000 to 2010. I address concerns about the influence factors and distribution of VC. The final section concludes.

2. Mechanism of VC to Technological Innovation

This article is still basing on a key assumption that technological innovation is produced as common goods, along with consumption, labor and capital is main factors, just like the research of us[18]. We can decompose the mechanism of VC to technological innovation by two effects: capital accumulation effect and incentive-supervision effect.

Referencing the endogenous economic growth theory of Aghion and Howitt (2004), this article is basing on a key assumption that R&D is produced, along with consumption and research by labor and middle product, just like consumption. Here we only explore stable state.

Assumptions are as follows:

Final goods: Hypothesis 1 Considering the multisectoral model with capital, only one final goods Y and can be used to consumption(C), investment(I) and

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R&D(N);

Hypothesis 2 Final good is now produced by a continuum of intermediate goods, indexed on the unit interval; while, the R&D is produced, along with the consumption and capital, by labor and intermediate goods, according to the production function

$$Y_t = C_t + I_t + N_t = \int_0^1 Y_{it} di = L_t^{1-\alpha} \int_0^1 A_{it} x_{it}^{\alpha} di \quad 0 < \alpha < 1 \tag{1}$$

Where L is the quantity of labor, and each X_{it} the total amount of intermediate good i, employed in the three uses.

Hypothesis 3 Final goods market is perfect competition, and final goods are constant returns to scale.

Intermediate goods:

Hypothesis 4 intermediate goods are monopoly market structure; each intermediate sector is monopolized by the holder of a patent to the latest generation of that good.

Hypothesis 5 Intermediate goods were produced only with capital, not labor.

Hypothesis 6 intermediate goods are the result of innovation, innovation is vertical, and is from R&D activity.

According capital accumulation effect, under six hypotheses of final good and intermediate goods, Aghion and Howitte deduced a relationship

$$\xi_t = \alpha^2 (L_t / k_t)^{1-\alpha} \tag{2}$$

ξ_t means the market rent rate of loan capital in period t; L means labor and α is its elasticity; K means capital and $1-\alpha$ is its elasticity. Capital lease cost and capital intensity is inversely, which means to increase of capital intensity will decrease the equilibrium rental rate, which monopolist paying for the capital. This can be accepted as a result of marginal gains of capital accumulation under a level of technology. For capital intensity is decided by capital and knowledge, so when the speed of capital accumulation is faster than technological innovation, capital intensity will increase, the lease cost of the intermediate goods producer will be low, vice versa. This is very important. It means faster capital accumulation leads lower capital cost. It causes the quickly financing, and more and more capital will invest in technological innovation. With the development of new technology, more and more capital is needed. When numbers of innovation enterprise emerge, their capital will require the increase of capital accumulation. While traditional financing mode unwilling or unable to provide money, the capital intensity will drop and restrain innovation. VC arise at historical moment, it enhances the capital intensity, and promotes the further development of technological innovation. This means VC plays a role as capital accumulation. Just for this, more and more new enterprises and new technologies have developed. New capital requirements are derived by these new developments. We can draw that the policies tend to capital accumulation are often conducive to technological innovation; VC can offer an opportunity to innovation.

Before talking about incentive-supervision effect, we must think how an enterprise keeps live? It depends on two aspects: one is the entrepreneurs must have innovation; the other is venture capitalist's support in capital and management. Thinking of these, note the live probability p, which can be expressed as

$$p = e_f p_a, \quad e_f \in \{0,1\} \tag{3}$$

e_f means the entrepreneurs efforts. If he doesn't work hard, e_f=0; only when he work hard, the enterprise can succeed, and e_f=1.

Venture capitalist can help the enterprise by his experience with probability of p_a. If venture capitalist won't give help, his contribution probability to successful enterprise is $1-p_a$.

Make assumption that venture capitalist asks to hold the enterprise shares (1-s) with the price of P=B+C in innovative stage, where B is the amount to pay for entrepreneur, C is the cost of start stage. Entrepreneur accepts this or to choose other stable salary W. if he accept, he will have s share and B. all this will be sign a contract. Both will try to gain the maximum profit R. if the enterprise can be sold out, the profit for venture capitalist will be:

$$\pi = p(1-s)R - P \tag{4}$$

Suppose market interest rate is r. For venture capitalist and entrepreneur hold common share, both will try in order to get expected profit. If consider further that during the enterprise operation process, venture capitalist can help it grow by giving suggestion, develop strategies, incentive, and supervision, which will form intangible costs note as ε. Basing this, we can get the express[18]

$$p = \frac{P(1+r)+\varepsilon}{(1-s)R} \tag{5}$$

According the incentive-supervision effect, the more venture capitalist pay, the higher probability enterprises succeed. Intangible cost is vital to enterprise. Rich experiences of venture capitalist can create a strong social network. The powerful incentive-supervision effect will lead more strong support, and more active innovation action. The probability of succeeding will increase. This is the fundamental advantage of VC to other capitals.

Theories tell us that VC has incentive effect to innovation. Conclusions supported the theory in different economical background. Is it the fact in China? We use Chinese data to find the conclusion. Many scholars had studied in many countries. Most of them use production function to discuss. We also did the work [18]. But in China, the period of VC growth is short, so macro data is too little to give out a credible outcome, which we can feel in many Chinese researches before. So here we will choose another mathematical method to overcome this limitation.

3. Data analysis

As we know, technological innovation can improve economic growth, so we should think it by economic

aspects. Our research showed innovation could be produced as common goods, so we referenced the input-output theory [18]. Here we should discuss the input and output indicators. Input factors include funds and human resource. Funds have two indexes: total amount of manage VC capital and government S&T appropriation. Human source input is weighed by R&D personnel full time equivalent (R&D personnel FTE). Output factor mainly uses patent applications. For data is not enough to construct a time series model, here we choose Grey Relational Analysis theory to find out the effect of VC to innovation. Grey relational analysis theory was proposed by professor Deng julong in 1982[19]. This theory looks the stochastic process as grey process and use specific method to describe the incomplete information system to make forecast, decision and control. The basic principle is to distinguish the degree of multiple factors density by comparing the geometrical relationship of statistical series. Its advantage is applicable to the multiple factors and imperfection data [20].

Its procedure is:

(1) Predefined sequence

Suppose X_0 is the variable stands for system behavior, its observation sample on k is $x_0(k)$(k=1,2,……,n), call $x_0(k)$=(x_0(1),x_0(2),……, $x_0(n)$) a system characteristic behavior sequence.

Suppose X_i stands for system factor, its observation sample on k is $x_i(k)$ (k=1,2,……,n), call $x_i(k)$=(x_i(1), x_i(2),……,x_i(n))(i=1,2,……,m) a system related factor behavior sequence. In this paper, k means time, x_i means a time series.

(2) Data standardize

Calculate mean ($\bar{x}$) of each sequence, then divided the original sequences by $\bar{x}$, and get new standardized sequence x_i':

$$x_i' = x_i / \bar{x} \tag{6}$$

(3) Difference sequence

Let x_i' differenced by x_0', we can get $\Delta_i(k)$:

$$\Delta_i(k) = \left| x_0'(k) - x_i'(k) \right| \tag{7}$$

(4) Gray Relational Degree

Here we calculate Deng's relational degree. First, calculate relational coefficientξ_{0i}(k):

$$\xi_{0i}(k) = \frac{\min\limits_i \min\limits_k \Delta_i(k) + \rho \max\limits_i \max\limits_k \Delta_i(k)}{\Delta_i(k) + \rho \max\limits_i \max\limits_k \Delta_i(k)} \tag{8}$$

Then relational degree $\gamma(x_0, xi)$ is:

$$\gamma(x_0, x_i) = \frac{1}{n} \sum_{i=1}^{n} \xi_{0i} \tag{9}$$

Basing $\gamma(x_0, x_i)$, we can know how density of x_0 with other x_i series, and can judgment the relationship of these series.

We calculate the GRD of total amount of manage VC capital, government S&T appropriation, R&D personnel FTE with patent applications, which can tell us the relationship of VC and technological innovation, meanwhile we can compare the effect of VC and government capital from 1995 to 2010.

We note:

x_0: patent applications(piece)

x_1:total amount of manage VC capital(hundred million yuan)

x_2: government S&T appropriation(hundred million yuan)

x_3: R&D personnel FTE(ten thousand year)

The mean of each sequence, in order, is 12114.20, 199.12, 436.57 and 81.44. Then we get the relation degree as table 1:

TABLE 1 Grey Relation Degree

time	X_1	X_2	X_3
1995-2000	0.5599	0.9315	0.8049
2001-2005	0.5728	0.8514	0.6810
2006-2010	0.6133	0.7494	0.7357

Data shows that even the GRD of government S&T appropriation is the highest in the three indexes, it droppers year by year(from 0.9315 to 0.7494). This implies the dependency of Chinese technological innovation to government capital is dropping. The GRD of VC and technological innovation is higher year by year (from 0.5599 to 0.6133).It just explains why the dependency to government dropped, for folk capital has expended its power day and day. The relation degree of R&D person falls firstly (from 0.8049 to 0.6810) then rise (from 0.6810 to 0.7375), which tells us R&D personnel is very important during innovative process.

To sum up, we can see that the effect of VC to technological innovation becomes more and more strong. Favoring the immature and startup enterprises, VC is the most matching capital form to technological innovation. Its character of distribution closely connects with the distribution of technology, especially reflecting in regional and industrial distribution. We can see that VC development has become important to Chinese enterprises. In order to acknowledge the VC in China, we research its distribution further.

4 Regional Distribution of VC

Most researches of the geographical characters are about America and Europe. A basic characteristic of venture capital is its spatial concentration. Just like economic activities venture capital funds and their investments are also geographically strongly concentrated. Experienced investigations confirms that VC always shows regional crowd with the financial centers and hi-tech regions [21][22][23][24]. Richard and Martin explores the role of VC in technological innovation and regional development [22][23]. Both aggregate data and a unique firm level data were employed to determine the location of major centers of VC, flowed of VC investments, and patterns of investment syndication or coinvestment among VC firms. They

thought VC was the most important in the US areas where it became a part of the "social structure of innovation". The most relevant elements of success are due to the regional gather, such as close distances (geographical concentration), clustering, personal relationships, quick sharing of information, personal networks, etc. Richard and Donald used metropolitan-level data on VC data and developed statistical models for both the supply and demand. Chinese researchers have some outcomes, but they are not reprehensive. For the data of Chinese VC is not easy to get, short time series cannot convince us enough, and the space research is difficult, too [25]. Here we use kernel density estimation to research the dynamic change of Chinese VC.

Kernel density estimation is the common method for data distribution research. Assume a random variable X, its density function $f(x)$ unknown, if $x_1, x_2, \cdots, x_N$ is a sample observation of X, its density function can be fetched from empirical function. It is:

$$F_N(x) = \frac{1}{N}\sum_{i=1}^{N} I(x_i \le x) \tag{10}$$

Which N is the number of observation, $I(z)$ is index function, z is the conditional relationship expression. When z is true, $I(z)=1$; when $\boldsymbol{z}$ is not true, $I(z)=0$. z of (1) is $x_i \le x$. x_i is the *ith* observation. When $x_i \le x$, $I(x_i \le x)=1$; or it equals to 0. So general kernel density estimation is:

$$\hat{f}_n(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right) \tag{11}$$

Which $K(\cdot)$ is kernel function, h is the window width.

This paper adopted Gauss normal kernel function, which

$$K(u) = (2\pi)^{-\frac{1}{2}} \exp(-\frac{1}{2}u^2) \tag{12}$$

Choose size of Chinese VC funds and numbers of Chinese VC funds from 2000, 2005, 2010 to show distribution of VC (figure 1). All data were from ChinaVentrue "CVSource" database.

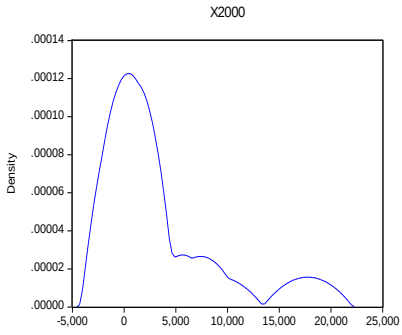

FIGURE 1. Size of VC funds distribution in 2000

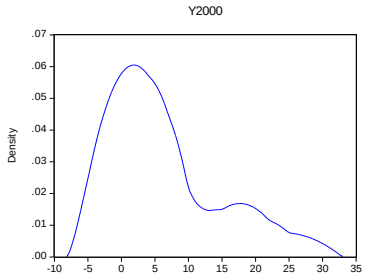

FIGURE2. Numbers of VC funds distribution in 2000

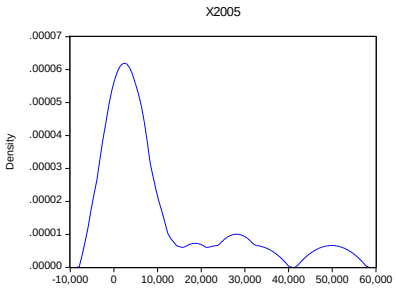

FIGURE 3. Size of VC funds distribution in 2005

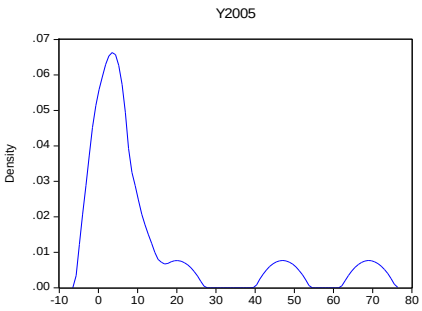

FIGURE4. Numbers of VC funds distribution in 2005

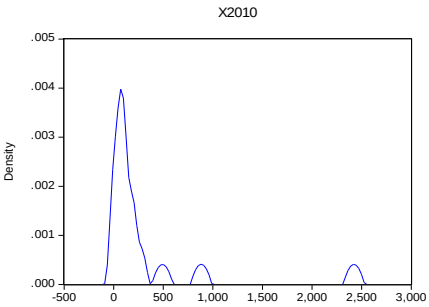

FIGURE 5. Size of VC funds distribution in 2010

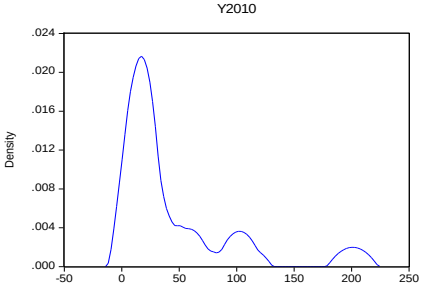

FIGURE 6.Numbers of VC funds distribution in 2010

These six distribution figures show that VC in China displays bipolar distribution. No matter size or numbers, the VC distribution lines are smoother in 2000 than 2010, and the gap becomes wider and wider over time. In most regions, VC's activity are low (around zero, the value of peak are higher). More and more VC funds concentrated in east, such as Beijing, Shanghai, Guangdong, Jiangsu and so on. We can draw scatters to show the Data shows VC is activity in east regions. Other regions center on the weak VC investment area. How to explain the disequilibrium? We give two reasons: one is the whole technology improvement level is low, so VC mainly depends on the economic environment. We have to admit that Economic disequilibrium is the main reason. In Midwest, VC couldn't find a good technological environment to be supported, so it develops slowly. The other is that east regions, especially Beijing and Shanghai, remain the far-and-away leaders in technology and VC investment development. We make two scatters to show VC and technological distribution (figure7 and 8). The index STPI means comprehensive index of the level of scientific and technological progress, estimated by Chinese Ministry of Science and Technology. Comparing with the Shanghai and Guangdong, the latter has obviously superior in high-tech industry development, but it is not the main area of VC investment. Why? We must note that Beijing and shanghai are the finance developed areas in China, so they can support active capital flow.

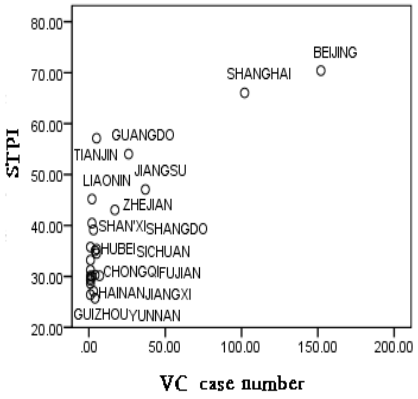

FIGURE7. STPI and VC case number

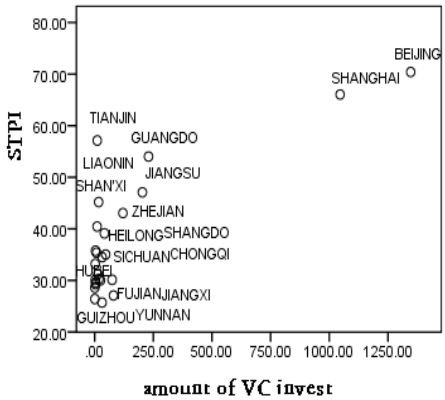

FIGURE8. STPI and amount of VC invest

5 Conclusions

By calculating the GRD, we compare the effect of VC and government capital. Conclusions support that VC has significant effect on Chinese technological innovation. VC can become an effective way for enterprises financing and technological innovation. While the development of regional economy is unequal, large gaps exist in VC activity in different regions. Most of VC concentrates in the southeast, for these regions have looser monetary policies. It's easy to match supply and demand of funds. VC can find ideal developed high-tech and to support it. So they absorb home and aboard capital effectively. If the unequal of regional economic intensifies, the distribution of VC will show polarization seriously. Innovation of financing is our urgently needed. Government should play an important role, especially in the Midwest regions. It's a good idea using governmental invest to attractive folk and aboard investment. With the completing of the investment environment and machine, governmental capital should withdraw gradually. Government should try to diversify the technology and investment market. Just to do these, Chinese economy can be droved quickly. We will accumulate related data, and research it further.

Acknowledgment

This article is supported by the project of the Development of Philosophy and Social Sciences Report of the Ministry of Education(No:11JBGP014), Program for the Philosophy and Social Sciences Research of Higher Learning Institutions of Shanxi province(No.2012230), Research Project of Philosophy and Social Sciences Research of Shanxi province (2012).

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