INNOVATION PERFORMANCE RESEARCH ON CHINA'S NEW GENERATION INFORMATION TECHNOLOGY INDUSTRY IN THE DIGITAL ECONOMY CONTEXT

Yangyang Huang
Business School, University of Shanghai for Science and Technology, Postgraduate, China

Guangkuo Gao
Business School, University of Shanghai for Science and Technology, Professor, China

Abstract

Under the background of digital economy, China's new generation of information technology industry is developing rapidly. The main purpose of our study is to explore the influencing factors of innovation performance of this industry. From a microcosmic point of view, this paper takes domestic listed companies belonging to the industry as samples. By drawing on the analytical framework of CDM model, this paper is to carry out an empirical research to analyze the relationship between innovation input, innovation output and innovation performance. The results show that there is a significantly positive correlation between R&D investment and the gross profit margin of enterprise product sales (an estimator for innovation output). The positive effect of innovation output (measured by gross profit margin of enterprise product sales) on innovation performance (measured by labor productivity) is significant. In addition, it also reveals that the enterprise's innovation performance is also influenced by per capita investment in fixed assets, turnover rate of fixed asset, employee quality, government support, spillover effect, etc. But industrial effect and industry-university-research cooperation have no significant impact on enterprise's innovation performance.

Keywords: R&D investment; CDM model; innovation output; innovation performance

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1. Introduction

The development of China's digital economy needs the prosperity of new generation of information technology industry. This industry contributes to the informatization of traditional industry and the industry upgrading. Under the background of digital economy, major countries in the world have paid great attention to the development of new information communication technology.

The new generation of information technology industry, is an emerging industry which is knowledge-intensive, technology-intensive and low consumption of material resources. Its basis of development is the breakthroughs in major technologies and urgent development demand. In the past two years, the breakthrough of quantum communication technology and the commercial trial of 5G mobile network have been the concentrated expression of the development of new generation information technology industry in china. Under the background of the digital economy, networking, cloud computing, as the core of the new generation of information technology industry, big data, and artificial intelligence technology, together play an irreplaceable role in promoting the development of the digital economy and Digital upgradation of traditional industries. With the characteristics of digitalization, networking, intelligence and integration, new generation of information technology industry has become one of the most innovative and active industries. And it is one of the seven strategic emerging industries in China.

As one of the most innovative industries, its creativity directly relates to the development of China's digital economy and informatization of traditional industries. This paper focuses on the innovation practice of micro-subject in the new generation of information technology industry. Through analyzing the influencing factors of innovation performance, our study attempts to explore the micro mechanism of innovation in this industry.

2. Theoretical and conceptual background

Innovation can be divided into non-technical innovation (organizational innovation, market innovation, etc.) and technological innovation (product innovation, process innovation, etc.)(see Geldes *et al.,* 2016). Innovation is the most important factor in maintaining a competitive advantage because innovation can improve the product and the production process, enabling businesses to survive in a changing environment (see Atalaya *et al.,* 2013). Joseph Schumpeter, founder of modern innovation theory, argues that innovation is a reorganization of factors of production (industry, market share, technology opportunities, etc.). These factors of production together have an impact on R & D investment and innovation decisions. Therefore, a new production function was constructed by Schumpeter. But there is a black box during the process of innovation, the study of innovation needs to be more in-depth. Henceforth, many researchers focus the study on innovation process.it is obvious that innovation process is complicated. So it is reasonable that researchers will easily neglect some significant factor when exploring the relationship between R&D and labor productivity (innovation performance).Some researchers find that there is a knowledge production function(innovation output function) playing an important role during the process of inputting R&D to increase labor productivity(see Griliches, 1991 &1994). By combining Schumpeter's modern innovation theory and the knowledge production function, Crépon *et al.* (1998) built the CDM model to analyze the relationship of innovation input, innovation output, and innovation performance from a microcosmic view. The model effectively overcomes the "black box" puzzle in the innovation process.

After the emergence of the CDM model, many researchers have applied this model to a series of empirical studies on enterprise innovation in many countries. Benavente (2006) studied nearly 500 firms in Chile, his research shows that firms with a large market input much more R&D to increase innovation output, then raise labor productivity. Peters (2008) launched his empirical research on German firms; according to his study, firm performance is increased with the improvement of enterprise innovation capability, that is to say, firm innovation contributes to promote firm's labor productivity, so that firms could get more economic benefits. To facilitate the interpretation of some economic phenomena, some researchers have improved the CDM model. Adding the factor of innovation spillover into the firm performance equation of CDM model, Aiello *et al.* (2009) analyzes the innovation situation of more than 1,200 manufacturing enterprises in Italy .adding the factors of innovation spillover in the enterprise performance equation of CDM model. The results show that the greater the spillover effect of R & D investment, the higher the innovation performance. Goya *et al.* (2016) analyze the impact that R&D expenditures and intra- and inter-industry externalities have on the performance of Spanish firms. As shown in their study, R&D expenditures do not have a direct impact on firm performance, but spillovers do.

3. Research methods and model building

3.1 Data sources and sample selection

Our study uses the financial indicators and other micro data of the listed companies of the new generation of information technology industry derived from the Wind Info. The span of this study is from 2013 to 2015, which mainly studies the data of listed companies of the industry above. As of December 31, 2015, there were 131 listed companies of new generation information technology in China's stock exchanges. To facilitate model building, this paper excluded 21 enterprises with incomplete input and output data of innovation, which means the enterprises lack of R & D investment, government subsidies, and major profits are eliminated by us. Finally, an effective sample of 110 enterprises per year is obtained, a total of 330 samples from 2013 to 2015.

3.2 Variable selection and model building

According to previous studies, this paper refers to the variables selected in the CDM model (see Crépon *et al.*, 1998), uses R&D investment intensity to indicate innovation input of an enterprise. For the selection of innovation output indicators, this paper selects gross profit margin of product sales to measure. Some researchers have taken the proportion of new product sales as an index to measure innovation output before, but it is difficult to obtain the data of new product sales of a company in the new generation of information technology industry. The index of gross profit margin of product sales can not only reflect the financial performance of enterprises, but also indirectly reflect the success of enterprise innovation (see Rothwell, 1992). Therefore, gross profit margin index can better reflect innovation output. And our study uses labor productivity (per capita industrial added value) to measure comprehensive innovation performance, per capita industrial added value directly reflects the effectiveness of enterprise innovation, and can be used to compare the innovation performance among enterprises.

Table 1. Variable Description

<table>
<tr><td colspan="3">Variable Description of Model 1</td><td colspan="3">Variable Description of Model 2</td></tr>
<tr><td>Innovation output (GPR)</td><td colspan="2">Mean value of gross profit margin of product sales (2013-2015)</td><td>Innovation performance (LnY)</td><td colspan="2">Labor productivity(Per capita industrial added value) of 2015</td></tr>
<tr><td>R&D intensity (CT)</td><td colspan="2">Cumulative R&D / Sales income(2013-2015)</td><td>Innovation output (GPR^*)</td><td colspan="2">Predicted gross profit margin of product sales of 2015</td></tr>
<tr><td rowspan="7">Other internal and external influencing factors (Vector X)</td><td>Enterprise cash flow (CF)</td><td>Annual average value of the ratio of operating net cash flow to enterprise income (2013-2015)</td><td rowspan="7">Other internal and external influencing factors (Vector Z)</td><td>Quality of employees (L)</td><td>Bachelor degree or above in 2015</td></tr>
<tr><td>Enterprise scale ($LnSIZE$)</td><td>Annual average of employees (2013-2015)</td><td>Turnover efficiency of assets ($LnTR$)</td><td>Turnover ratio of fixed assets in 2015</td></tr>
<tr><td>Capital intensity ($LnECD$)</td><td>Average annual fixed capital per capita (2013-2015)</td><td>Capital intensity ($LnECD$)</td><td>Per capita fixed assets in 2015</td></tr>
<tr><td>Government support (Gov)</td><td>Annual average of government subsidies in R & D investment (2013-2015)</td><td>Government support (Gov)</td><td>Annual average of government subsidies in R & D investment (2013-2015)</td></tr>
<tr><td rowspan="3">Industry-university -research cooperation (ISR)</td><td rowspan="3">Whether adopted industry- university-research cooperation model during study period? yes= “1”,no= “0”</td><td>Spillover effect ($LnSpill$)</td><td>(R&D * Regional innovation comprehensive coefficient) in 2015</td></tr>
<tr><td>Industry effect (Q)</td><td>Tobin’s Q</td></tr>
<tr><td>Industry-university -research cooperation (ISR)</td><td>Whether adopted industry- university-research cooperation model during study period? yes= “1”,no= “0”</td></tr>
</table>

In addition, this paper takes the impact of innovation spillovers on innovation performance into consideration. Traditional research methods of innovation underestimate the effect of R&D, because they neglect the effect of spillover (see Mairesse *et al.*, 2005). The innovation spillover effect is equal to the product of R & D investment each year and the comprehensive coefficient of regional innovation each year (see Lu, 2014). The comprehensive coefficient of regional innovation can be obtained from the Report on China's Regional Innovation Capability (2013-2015). Since innovation patterns of firm have influence on the firm performance (see Karabulut, 2015); and cooperative innovation effect may have impact on the innovation performance (see Xie, 2012). This paper uses the dummy variable industry-university-research cooperation as an influential factor of enterprise innovation performance (see Balconi *et al.*, 2006). If an enterprise can maintain a close and long-term cooperative relationship with the upstream and downstream industries, and establish a stable cooperative relationship with the relevant institutions and universities, it shows that the enterprise has adopted the industry-university-research cooperation, then the dummy variable is equal to 1, on the contrary, it is 0. This indicator can be obtained manually from the corporate financial report. Finally, it is considered that the innovation of listed companies may be affected by market and industry environment, therefore, this paper uses Tobin's Q to measure industrial effect (see Mcgahan, 1999). In China's stock market, generally speaking, Tobin's Q value of innovative enterprises is very high, and they has been sought after by investors. This will encourage enterprises to actively innovate. The Tobin's Q value is equal to (stock price * equity + debt) / total assets, all using the data at the end of the year.

Thus, according to the framework of CDM model and the improved model by some researchers (see Griliches, 1994; Wieser, 2005), On the basis of previous research, this paper constructs the following improved enterprise innovation output equation model (Model 1) and the improved enterprise innovation performance equation model (Model 2):

$$GPR_i = \alpha_0 + \alpha_1 CT_i + \alpha_2 \mathrm{X}_i + \varepsilon_1 \tag{1}$$

$$LnY_i = \beta_0 + \beta_1 GPR_i^* + \beta_2 LnECD_i + \beta_3 \mathbf{Z}_i + \varepsilon_2 \tag{2}$$

The description of dependent and independent variables is demonstrated in Table 1.

4. Empirical analysis

4.1 Pearson correlation test

Table 2. Pearson Correlation coefficients of major variables

Variables	LnY	CT	GPR	CF	$LnSIZE$	$LnECD$	L	$LnTR$	Gov	$LnSpill$	Q	ISR
LnY	1.000											
CT	0.136	1.000										
GPR	0.404***	0.601***	1.000									
CF	0.096	0.382***	0.452***	1.000								
$LnSIZE$	-0.274***	-0.251***	-0.319***	-0.041	1.000							
$LnECD$	-0.028	-0.108	-0.263***	0.160*	-0.098	1.000						
L	0.535***	0.457***	0.428***	0.115	-0.145	-0.353***	1.000					
$LnTR$	0.387***	-0.097	0.023	-0.277***	0.128	-0.747***	0.424***	1.000				
Gov	-0.153	0.028	-0.175*	0.070	-0.270***	0.420***	-0.033	-0.428***	1.000			
$LnSpill$	0.155	0.114	-0.109	0.040	0.771***	-0.047	0.238**	0.243**	-0.269***	1.000		
Q	0.329***	0.290***	0.555***	0.223**	-0.479***	-0.221**	0.347***	0.139	-0.088	-0.294***	1.000	
ISR	0.095	0.012	0.058	-0.129	0.114	0.005	-0.027	0.026	-0.146	0.150	-0.122	1.000

Notes: *** Significant at 1 %, ** significant at 5 %, * significant at 10 %.

As shown in Tables 2, the results of Pearson correlation test of the variables show that the correlation between most variables is significant, reaching a significance level of 5% or more, indicating that there is a certain endogeneity among the variables. However, it is generally believed that when the correlation coefficient between the two variables reaches 0.8 or more, there will be multiple co-linearities between the two variables. It is found that the correlation coefficients among the variables selected in this paper are much lower than 0.8, so that there is no multiple collinearity between the explanatory variables. Although some correlation coefficients are relatively large (Table 2), due to the existence of a certain endogenous in innovation activities, our study do not remove any variables selected above.

4.2 Model estimation results

Table 3. Regression results of Model 1

GPR	Coef.	Robust Std.Err.	t	$P>\|t\|$
CT	0.7321^{***}	0.2431	3.01	0.003
CF	0.4771^{***}	0.1052	4.53	0.000
$LnSIZE$	-0.0451^{***}	0.0087	-5.20	0.000
$LnECD$	0.0457^{***}	0.0143	3.20	0.002
Gov	-0.1932^{**}	0.0852	-2.27	0.025
ISR	0.03844^{*}	0.0224	1.72	0.089
_cons	0.7297^{***}	0.0889	8.21	0.000
$R-Squared$	0.58			
F	15.95			

Notes: *** Significant at 1 %, ** significant at 5 %, * significant at 10 %.

Table 4. Regression results of Model 2

LnY	Coef.	Std.Err.	t	$P>\|t\|$
GPR^*	1.4785^{***}	0.4296	3.44	0.001
$LnECD$	0.7359^{***}	0.0753	9.77	0.000
L	0.7739^{***}	0.2183	3.55	0.001
$LnTR$	0.6809^{***}	0.0770	8.85	0.000
Gov	-0.2361	0.3133	-0.75	0.453
$LnSpill$	-0.0160	0.0402	-0.40	0.691
Q	0.0597^{**}	0.0255	2.34	0.021
ISR	0.1303	0.0809	1.61	0.110
_cons	-1.0803^{***}	0.5086	-2.12	0.004
$R-Squared$	0.67			
$Adj-R-Squared$	0.65			
F	26.78			

Notes: *** Significant at 1 %, ** significant at 5 %, * significant at 10 %.

In order to avoid the interference of heteroscedasticity, this paper uses robust OLS to estimate Model 1, Then, according to the regression result of Model 1 (Table 3), the gross profit margin of product (GPR)sales is predicted in 2015,the predict value is GPR^* which is regarded as one of the explanatory variable in Model 2.Finally, our study uses OLS regression to estimate Model 2 (Table 4), and then White Test is applies to examine whether heteroscedasticity is existed in Model 2(Table 5).The regression results show that the regression goodness of the model 1 and the model 2 is good, and there are no heteroskedasticity and multiple collinearity problems in the two models. Most of the coefficients of the explanatory variables are tested significantly.

Table 5. White's test results

white's test for Ho:homoskedasticity against Ha:unrestricted heteroskedasticity	
Test results	Chi2(43) = 48.02
	Prob>Chi2 = 0.2766

4.3 Conclusions

4.3.1 Analysis of influencing factors of innovation output

First, the gross profit margin (GPR) is positively related to R & D investment (CT), operating cash flow (CF) and capital intensity of enterprise ($LnECD$), correlation coefficients are 0.73 , 0.48 and 0.05 respectively (Table 3). This shows that the increase of R & D investment (CT) could provide a good environment for enterprise product innovation and technological innovation. Then enterprises can form market barriers by producing new products, and form technical barriers by owning new technology. Ultimately there will be an increase in gross margin for product sales. As regards the operating cash flow (CF), only cash flow from the production and operation of enterprises can accumulate funds for enterprises, thus providing financial support for the products and technological innovations of enterprises. The capital intensity ($LnECD$) directly reflects one enterprise's actual strength and confidence of self-development. It contributes to the increase of new product sales, which means a positive impact to the innovation output.

Second, the innovation output (GPR) is negatively related to enterprise scale ($LnSIZE$) and government support (Gov) (Table 3).Generally speaking, an enterprise with a large scale is more likely to obtain scale returns. But as knowledge-intensive and technology-intensive enterprise, its demand for top talents is so urgent that needs to undertake a great deal of staff salaries. This part of the cost of manpower will be allocated to the product, resulting in lower gross margin which means lower innovation output. In the new generation of information technology industry, the development of an enterprise needs adequate fixed assets to support research activities and production. It is surprising to find that the impact of government support (Gov) on the innovation output (GPR) is negative. But this reveals a new phenomenon: some enterprises lack the motivation to carry out independent research and development, they just blindly want to get more government subsidies. It causes low efficiency of government support, ultimately could not improve innovation output. The existence of adverse selection is harmful the sustainable innovation.

In addition, it can be found that whether a firm adopting industry-university-research cooperative model exerts insignificant impact on innovation output (Table 3).Many companies in the new generation of information technology industry tend to research independently, it reveals a problem that their innovation is not open enough. Firms in the industry need to change their mindset, should learn to take advantage of external resources with a positive and open mind.

4.3.2 Analysis of influencing factors of innovation performance

First, there is a significantly positive correlation between innovation output (GPR) and innovation performance (LnY) (Table 4), the correlation coefficient is 1.48 which means strong elasticity. With the increase of innovation input (CT), enterprises have more motivation to apply new technology and create new products. Therefore, enterprises could obtain more market share and gain more profit in the fierce market competition. Fundamentally, Per capita industrial added value (labor productivity) will be improved.

Second, the enterprise's capital intensity ($LnECD$) and quality of employees (L) have significantly positive correlation with innovation performance (LnY) (Table 4). The correlation coefficients are 0.74 and 0.77 respectively. This result is consistent with the inherent meaning of Solow Growth Model. The capital intensity ($LnECD$) directly reflects one enterprise's actual strength and confidence of self-development. The quality of employees (L) is a basic standard to measure the ability of one enterprise's innovation. Those who have mastered the high-tech talent, the more likely they will seize the dominant position in the fierce market competition.

Third, there is a significant positive correlation between the fixed assets turnover rate ($LnTR$), and innovation performance (LnY), and the correlation coefficient is 0.68 (Table 4). The turnover of fixed assets is an important indicator to measure the operation ability of an enterprise's assets. In the new generation of information technology industry, firms have more requirements on the new high-tech equipment and modern laboratory. The speed of fixed-assets' turnover directly reflects one firm's comprehensive ability of product innovation, market innovation, management innovation, technology innovation, etc. As enterprises in the new generation of information technology industry, their product could obtain relatively high added value. But it can be ignore that these firms' operation risk is great; once they begin a new research plan and a new production line, they may face the risk of a longer payback period due to market changes or rival competition.

Fourth, Tobin's Q (an estimator of industry effect) has a weak positive correlation with innovation performance (LnY) (Table 4).Tobin's Q, also known as asset replacement rate, is one of the market indicators that reflects the market performance of listed companies. With the increase of Tobin's Q, the higher the premium level of the corporate assets. Our research samples are all high-tech enterprises, their price-earnings ratio is generally high. But in China's stock market, Tobin's Q could not demonstrate listed companies' real operation and innovation performance. The obvious reason is that there are too many speculators in China's stock market; their irrational pursuit raised the stock price during the study period, leading to the departure of Tobin's Q and firm's real operation performance and innovation performance.

Fifth, there is a negative correlation between the innovation performance (LnY) and innovation spillover ($LnSpill$), government support (Gov), but not significant (Table 4). Spillover means that the company's innovation income could not be completely possessed by itself. It is not surprising that innovation activities, more or less, have externality. Once a new innovative product appears in the market, it will be quickly imitated by competitors with lower cost than original innovation does. This phenomenon is usually called technology spillover effect. There exists adverse selection when enterprises apply for R&D subsidies from government. Government support (Gov) seems more appealing than their determination of independent innovation. Thus, government support causes non-positive effect on innovation performance.

Sixth, there is a weak positive correlation between industry-university-research cooperation (ISR) and innovation performance (LnY) (Table 4). According to our study, half of the firm samples adopt this kind of innovation pattern (industry-university-research cooperation), but do not get the desired effect. The reason may be that this innovation pattern is still in the stage of attempt; and there will be no obvious effect in the short term. The innovation pattern of industry-university-research cooperation is conducive to transform knowledge into productive forces, this can be seen from the positive correlation (although not significant) between ISR and LnY.

5. Enlightenment and suggestions

Under the background of digital economy, government support is essential for the development of the new generation of information technology industry. However, empirical analysis shows that the government's direct subsidy support for next-generation information technology companies may have reverse effect on innovation performance. Therefore, government should make a change on subsidy policies. Government should learn to combine government incentives with market-driven power, so as to stimulate and guide the firm’s innovation. Innovation itself is a market behavior, government support plays a distinctly subsidiary role during the process. That is to say, government subsidy ought to be innovation-output-oriented. In the condition of result-oriented, it can avoid the adverse selection phenomenon during government support.

On the corporate side, firms in new generation of information technology industry should attach more importance on R&D investments (including capital, talents). Not similar to some traditional industry, this industry is knowledge-intensive and technology-intensive; the resource of scarce talent could boost technology innovation, raise the efficiency of innovation and create practical benefits. In addition, firms in this industry should be more open-minded during the innovation process. Innovation is a complex and systematical engineering work which needs cooperation. It requires that firms of the new generation of information technology industry ought to adopt a much more proactive approach to innovation. They should actively establish cooperative relationship with scientific research institutes and universities worldwide. By adapting innovation pattern, firms seek survival and development in the era of dramatic technological change.

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