The Impact of Digital Economy on Innovation Behavior: A Study on Chinese Market

Zehao Jing[1]

[1]*Dana and David Dornsife College of Letters, Arts and Sciences, University of Southern California, Los Angeles, 90007, the United States of America*
[*]*Zehao Jing. Email: zehaojin@usc.edu*

ABSTRACT
In the new era of information, innovation has been a vital factor for technology and social development. As a product of innovation between economics and IT, digital economy expands its width and depth and is becoming an important pillar of the economy. If the effect of digital economy on innovation can be ascertained, digital economy may be an engine for innovation with correct guidance, and the digital economy-innovation-digital economy positive feedback could be expected. Based on data from Chinese Statistical Yearbook and Financial Inclusion Index from Peking University from 2012 to 2020, I established a linear regression model to include potential factors representing digital economy and two dependent variables on behalf of innovation input and output. The result shows that digital economy truly magnify innovation process in China, but the outcome is more intricate. This paper shows it is indispensable to pay more attention to service quality and explore the scope of business services, maintain digital transformation, improve service mobility and convenience, and attract more employees, compared with expanding market scale and consumer groups. The government should also take responsibility and invest resources in education to help society improve education level.

Keywords: *Digital Economy, Innovation, Digitalization.*

1. INTRODUCTION

Innovation, as a process to introduce new ideas into products or procedures that can generate value, is one of the most important impetus for the development of society. Many advance tools and technologies such as computer are applied to improve productivity and promote economic development. Therefore, it can be said that innovation drives social progress. Digital economy, a fashionable term combining digital technology and economic, also have the potent to intensify economic life, and this effect induce the attention of countries all over the world. For example, in Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035, China is plan to support digital economy to push industry digitalization, facilitate digital transition in the whole industrial chain and accelerate digital services in both urban and rural areas[1]. However, the relationship between economics and innovation is no longer simply unidirectional. According to the Oslo Manual, an instruction for utilizing innovation data published in 2005, said that as the world economy, especially globalization has made the access to information more easily and provide opportunities for more efficient organizational forms for global supply chains [2]. This means that economic development also promotes innovation. If the same situation can be observed on digital economy, or does digital economy back feed innovation? That is what I will present and illustrate in this paper. I hope that I can find a good growth route for digital economy, and introduce it to enhance social development and national economic more efficiently by researching the effect of digital economy on innovation process. I find that there is not too much literature about the relationship between innovation and digital economy, or how much does digital economy back feed and promote technology innovation, so this is a potential direction for research.

2. LITERATURE REVIEW

Digital economy was born with the development of electronics technology. Since the mid of 1990s, the evolution of computer and internet induced a new way of economics growth, which needs a specific definition.

According to Tapscott (1996), the digital economy "combined intelligence, knowledge, and creativity for breakthroughs in the creation of wealth and social development" [3]. This is the definition about the modality of digital economy. Furthermore, Margherio said in 1999 that the four segments of digital economy are "Building out the Internet ... Electronic commerce among businesses ... Digital delivery of goods and services ... Retail sale of tangible goods", defining the scope of digital economy [4]. After years of development in computer technology, the definition of digital economy also changes and extends in some degree. The report of Bureau of Economic Analysis of U.S. Department of Commerce about defining and measuring digital economy in 2018 includes such points in its definition: (1) the digital-enabling infrastructure needed for a computer network to exist and operate, (2) the digital transactions that take place using that system ("e-commerce"), and (3) the content that digital economy users create and access ("digital media"). Here some fashionable concepts are covered in this definition. The internet of things is part of digital-enabling infrastructure, and B2B, B2C, P2P are dimensions of e-commerce [5]. BEA also regards big data as a form of digital media, because big data could be used in gather information about consumer behavior or preferences.

It is clear that digital economic is associated with technology innovations. In fact, the relationship between digital economy and innovation is close and indivisible. Kangning Xu wrote in 2021 that digital economy accelerates worldwide industrial structure changes, promotes economic growth and development of new technology in an analysis about the influence of digital economy to the world economic [6]. He claims that digital economy is supported by internet and information technology, and the progress of digital economy calls for more advance technology. For example, the high need of digital product in digital economy require sophisticated integrated circuit, thus pushing chip standard from 14 nanometers to 5 nanometers. Carlsson (2004) claims that if the demand side （digital economy）responds appropriately—i.e., if the competence bloc succeeds in selecting and supporting viable new products—economic growth results [7]. Some practical analysis and researches have showed that digital economy positively influence the society. Xiao's (2021) research on "Regional Green Total Factor Productivity" shows that the development of digital economy is conducive to the promotion of regional green total factor productivity, and there are effects of energy saving and technological innovation [8]. What's more, Lei Teng (2021) revealed that innovation in digital economy is beneficial to economic growth in countryside, calling for further financial inclusion innovation based on rural areas [9].

Some potential channels may explain the mechanism of innovation promoting by digital economy. First of all, information technology can reduce people's search cost and coordination cost, and consumers and producers can make barrier-free transactions in the era of e-commerce, reduce transaction cost, accelerate technological innovation and reshape product value chain (Anderson, 2002). In this way, online platforms expended by e-commerce will help the producers to gather information and benefit the speed of innovation [10]. Pee emphasizes that e-commerce in the era of digital economy provides channels for consumers to understand and participate in product production and manufacturing, and e-commerce enterprises and consumers should be encouraged to jointly develop new products [11]. Since the r&d of new products is an important part of the enterprise innovation end, the cooperation between enterprises and consumers in the product design stage can promote the r&d of new products. Mahr and Lievens point out that producers can reduce search risk by engaging consumers in innovative activities through Internet platforms [12]. Because producers can benefit from innovation activities, they are encouraged to collect innovation information to a certain extent. In the era of digital economy, e-commerce can effectively solve problems such as geographic distance of information and cultural differences, facilitate communication between consumers and producers, enable producers to obtain product innovation information timely, reduce the risk of failure to search for innovation information, improve the enthusiasm of regional technological innovation, and increase the input of innovative labor force

3. DATA AND METHOD

Here is a direct indicator for digital economy, called Financial inclusion indicator presented by institute of digital finance Peking University. This indictor includes the coverage, depth and degree of digitalization of digital economy. What's more some other factors representing the degree of internet development should also be included such as number of Internet users per 100 people and Total telecom service per capita. Relative data is available on CHINA CITY STATISTICAL YEARBOOK. Last but not least, I should control some important factors in case that they may disturb the result. For instance, the promotion of GDP and urbanization will definitely influence both digital economy and technology, even in the same direction, so I must control these external factors to prevent spurious association. The time scope of data is from 2012 to 2020, because only in this time scope the data are available

The method of this research is mainly linear regression. I will select dependent variables and independent variables to research how one potential factor will affect innovation. Now I assumed that the dependent variable is the amount of patents and R&D cost about technology innovation in China, since the amount of patents is an indicator for innovation. Then the core independent variable is the degree of digital

economy development. The selected independent variables and their variable names are listed in Table 1 (all variables are in per capita standard and discounted by CPI based on 2010 level).

Table 1. List of dependent variables

Variable Name	Independent Variables
bband1	Broadband access number
telserv1	Telecommunication service volume
mbuser1	Number of mobile phone users
cable1	Length of long-distance cable
soft1	Income of software industry
emp_soft1	Total number of employees in software industry
gdp1	Gross regional domestic product
urb1	Urbanization level
inf_rail1	Infrastructure level measured by length of railway
inf_road1	Infrastructure level measured by length of road
edu1	Education level
fl_wid	Financial inclusion index measuring the width of e-commerce
fl_dep	Financial inclusion index measuring the depth of e-commerce
fl_digi	Financial inclusion index measuring the digitalization level of e-commerce

Below is the model for my research.

$$rd_{it} = \alpha + \beta_{j1} * internet_{j1it} + \gamma_{j2} * ecommerce_{j2it} + \delta_{j3} * control_{j3it} + \varepsilon_{it} \quad (1)$$

$$patent_{it} = a + b_{j1} * internet_{j1it} + c_{j2} * ecommerce_{j2it} + d_{j3} * control_{j3it} + \varepsilon_{it} \quad (2)$$

Here rd_{it}, $patent_{it}$ represents R&D and amount of patent, α, a means constant term, b_{j1}, c_{j2}, d_{j3}, β_{j1}, γ_{j2}, δ_{j3} are coefficients of variables in each category. $internet_{j1it}$, $ecommerce_{j2it}$, $control_{j3it}$ stand for the j1th/j2th/j3th variable in measure of internet, measure of e-commerce, control variables per capita at time i in area t. ε_{it} is random disturbance term. All terms are adjusted by CPI to real number. After collecting data, I plan to do a panel data analysis based on every provinces' data in each previous year. All of the variables are per capita data, to fit the organization of financial inclusion index, and all of the variables are discounted by CPI to get the real number.

4. RESULTS AND DISCUSSION

Table 2. Regression Result

VARIABLES	(1) rdcost1	(2) patent1
bband1	21.745***	10.031
	(3.51)	(1.23)
telserv1	-7.056	4.066
	(-0.24)	(0.19)
mbuser1	2.810	-4.291*
	(1.54)	(-1.80)
cable1	0.195***	0.193***
	(5.41)	(5.66)
soft1	0.009	-0.012
	(0.76)	(-0.40)
emp_soft1	-296.814***	1,040.469***
	(-5.29)	(11.79)
gdp1	-0.018	0.156
	(-0.04)	(0.45)
urb1	-0.000***	-0.000
	(-2.68)	(-0.45)
inf_rail1	-1.298***	-1.339***
	(-4.20)	(-5.54)
inf_road1	-0.153***	-0.138***
	(-8.29)	(-7.71)
edu1	0.415***	0.309***
	(6.29)	(4.81)
fl_wid	-0.040***	-0.017
	(-3.98)	(-1.55)
fl_dep	0.016***	0.014**
	(2.76)	(2.08)
fl_digi	0.007	0.009**
	(1.55)	(1.98)
Constant	-1.289	1.981
	(-0.84)	(1.07)
Observations	279	279
R-squared	0.682	0.877

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

My regression result in Table 2 shows an interesting result, and here I will analyze the result. There are mainly two regressions with two different dependent variables, R&D cost and the amount of patent. I choose robust standard error in my regression to take heterogeneousness into consideration and make my result more practical. Fortunately, the two regressions on R&D cost and amount of patent respectively have a seemingly nice R-square. The values are acceptable for a macroscopic analysis, so I am confident to continue my analysis. The critical value

First, I focus on the regression on R&D cost. Though many coefficients shows insignificant, there are still much to analyze. In digital technology part, the coefficients of broadband access number, length of long-distance cable, number of software industry employees are significant. The coefficient of broadband access number is 21.74522, which means that each additional broadband access will increase the R&D by nearly 21.74

Yuan on average. With a high t-value, 3.51, and low p-value, 0.001, this result is very positive significant. This shows that the popularity of broadband will do good to R&D cost. The volume of telecommunication service, number of mobile phone users, income of software industry are all insignificant, showing that the development of cell phone market size is not an important factor for R&D cost, and the operation situation of telecommunication service and software industry will not influence innovation input apparently. The length of long-distance cable has positive effect on R&D cost, which means that the communication capacity for telecommunication will benefit innovation. Averagely, one additional kilometer of long-distance cable contributes to R&D cost by about 1950 Yuan. Strangely, the number of employees in software industry have negative significant effect on R&D cost, the marginal effect of which is -296.81. It seems that more employees in software industry will decrease innovation input. This result may contradict to our common sense and this should be one of my characteristic findings. The results in financial inclusion index are also interesting. The width of e-commerce affect R&D negatively and the depth of e-commerce will increase R&D cost. The result is consistent with that in digital technology part, more participants in e-commerce and telecommunication do not promote innovation input condition. The depth of e-commerce, or various business in e-commerce including insurance and investment, is positively conducive to innovation input. Digitalization degree is not a critical factor. Then let's look at control variables. Coefficient of GDP per capita is not significant. Level of education reasonably positively influence R&D cost, but the degree of urbanization and infrastructure are negatively correlated with R&D cost.

Second, I focus on the regression on amount of patent. Here some changes happen compared to the case in the regression on R&D cost. The effect of broadband access number turns insignificant for amount of patent. Telecommunication service, total number of mobile phone users, and income of software industry are not so influential to innovation output according to these insignificant coefficients. Length of long-distance cable still presents a positively significant effect on amount of patent, where one more kilometer of long-distance cable will increase the amount of patent by 0.1929 on average, illustrating that communication capacity is an important factor as before. Number of employees in software industry, however, positively benefit the amount of patent. Based on the regression data, one additional employee in software industry will promote the enhance the amount of patent by almost 0.1. This phenomenon displays a distinct characteristic for employment situation in software industry. Then in financial inclusion index part, the result changes dramatically. Width of e-commerce becomes unimportant for amount of patent, while the digitalization degree of e-commerce is positive significant now. The depth of e-commerce remains unchanged, embodying that the volume of e-commerce matters to innovation output. Control variables perform similarly compared to the regression on R&D cost. GDP per capita is not influential, infrastructure have negative effect and higher education level boost innovation output. Nevertheless, urbanization level have no obvious impact on amount of patent.

From above results, digital economy really correlates with innovation in China. However, this effect is not in a simple form. First of all, many variables are not statistically significant, such as volume of telecommunication service, number of mobile phone users and income of software industry. Potential factors related to innovation input and output are concentrated into less factors that are significant. Second, changes in significance is evident between two regressions on R&D cost and amount of patent. For example, number of broadband access is significant in regression on R&D cost and in regression on amount of patent it changes to be insignificant. What's more, number of employees in software industry is negatively significant in regression on R&D cost, while in regression on amount of patent it become positively significant. Third, the effect of digital economy is complicated. Just as the employment in software industry above, it have the opposite influence on innovation input and output respectively. In financial inclusion index measurement, though depth and digitalization level of e-commerce are positively significant or insignificant, the width of e-commerce do harm to R&D cost. It prevents looking at the digital economy from a single perspective.

The data is worth to do some analysis. In our common understanding, innovation is a product by economic and technology development, so every factor related to economic and technology will influence innovation process more and less. Many variables here are not significant in regression on innovation, even GDP per capita, which illustrates the deviation of objective fact from our assumptions. Such anomaly is always caused by other variables with more explanatory power, and it is just the embodiment of my research value to figure out true factors that affect innovation input and output. As for some coefficients that are negatively significant, it is also based on the real situation of the data. For instance, infrastructure level in two separate regressions are all negatively significant, and in this way I will say infrastructure hampers innovation input and output. But does it necessarily mean the infrastructure disturb innovation process? If looking at the data, I will find that areas with high innovation input and output are not "big" enough, like Beijing and Shanghai, two municipalities directly under the central government in China. It is almost impossible to make them build longer railway and road than other provinces due to their city sizes, so the negative correlation between infrastructure level and innovation output and input accords with the actual

circumstance. The different effects of employee number in software industry probably reflect a kind of allocation problem. If more people enter software industry, then lower proportion of labor force supply other industries, leading to less demand for innovation among the whole society, thus decreasing the R&D cost. At the same time, more people in software industry will generate more ideas, advancing innovation output.

In conclusion, digital economy really back feeds innovation whether from hardware improvement or software development. But the evolution of digital economy needs a clearer direction in order to let it easier to innovate. For operation activities in digital economy, it is necessary to pay more attention to the quality of service, digging range of business services, instead of continuing expanding market size and consumers. I recommend relative firms to keep digital transformation, improve mobility and convenience of services and attract more employees. In this way, holding all other factors unchanged, digital economy could provide more patents without increasing R&D cost sharply. In other words, less investment can bring more return. The government should take responsibility too, put resources into education field to help the society improve education level. It is not just a spur to innovation, but also a move that benefits the country and the people.

5. CONCLUSION

There are some defects and limitations in my research. Firstly, because of my lack of personal power, funds and ability, I have limited access to data. Since digital economy started in mid-1990s, the best dataset should include data from mid-1990s, though I can only find the data available from 2012. I will appreciate it if further researches could use a broader database with much longer time horizon, which may ensure more accurate and practical results. Secondly, my research method has more room for improvement. For example, I can format an index by other variables in my own to represent industry development situation. The index may include variables that measure digital technology such as length of long-distance cable can be integrated into a new index weighted by some kind of proportions. Unfortunately, I cannot find a suitable paper to construct such index. Further researches can focus on this aspect. Last but not least, some factors still require deeper explanations. Width of e-commerce, one of the financial inclusion index measurements, show negative effects to R&D cost, with no apparent reason. I hope future researches could go further and answer those anomalies.

REFERENCES

[1] XNA(Xinhua News Agency). *Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035*. Xinhua News Agency, 2021

[2] I. I. Data. "Oslo manual." *Paris and Luxembourg: OECD/Euro-stat, na dan* 19 (2005): 2021.

[3] D. Tapscott. *The digital economy: Promise and peril in the age of networked intelligence*. New York: McGraw-Hill, 1996.

[4] USDOC (United States Department of Commerce). *The emerging digital economy*. US Department of Commerce, 1998.

[5] K. Barefoot, et al. "Defining and measuring the digital economy." *US Department of Commerce Bureau of Economic Analysis, Washington, DC* 15 (2018)

[6] K. Xu. The profound impact of digital economy on the world economy and its global governance. *Journal of South China Normal University(Social Science Edition)* 1.1(2022): 1-10

[7] B. Carlsson. "The Digital Economy: what is new and what is not?." *Structural change and economic dynamics* 15.3 (2004): 245-264.

[8] Y. Xiao, Y. Jiang. The Influence of Digital Economy on Regional Gren Total Factor Productivity. *Science Technology and Industry* 21.12(2021): 21-25.

[9] L. Teng, H. Zhang and S. Tang. Digital financial innovation and rural economic development from the perspective of Inclusive. *The World of Survey and Research* 12 (2021): 34-42.

[10] P. Anderson, E. Anderson. The new e - commerce intermediaries. *MIT Sloan Management Review* 43.4 (2002): 53.

[11] L. G. Pee. Customer co-creation in B2C e-commerce: does it lead to better new products. *Electronic Commerce Research* 16.2 (2016): 217-243.

[12] D. Mahr, D. Lievens A. Virtual lead user communities: drivers of knowledge creation for innovation. *Research Policy* 41.1 (2012): 167-177.