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Empirical Study on Discontinuous Innovation Affected by Technology Policy of Beijing

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Abstract: In recent years, discontinuous innovation has become a key factor of promoting industrial development and economic growth and it is the dominant innovation model which is developed by more countries. Chinese economic system is based on macro-control, so developments of many fields depend on national policy. The relation between discontinuous innovation and related policies need to be clear urgently. First, the number of technical personnel and technology funding was used in characterizing science and technology policy of Beijing and the number of patents for inventions was used in characterizing discontinuous innovation in this paper. Second, the cointegration analysis among three groups of data was carried on. At last, the fact was confirmed that science and technology policy of Beijing had a significant role in promoting to discontinuous innovation.

Key words: Discontinuous innovation, science and technology policy, cointegration analysis, macro-control

INTRODUCTION

In recent years, with the rapid development of science and technology, innovation has become the core development strategy for all countries over the world. To a company or a country, innovation is the key of survival and development (Weigelt and Sarkar, 2012).

For an enterprise, innovation is the basis to improve its competitiveness and continue to meet users' need. Now, consume consciousness of user's is also innovated constantly. So an enterprise can just win user's favor only when enterprise has an insight to this change (Ling and Yuan, 2012).

Innovation can be divided into continuous innovation and discontinuous innovation. So-called continuous innovation is small change or improvement on the basis of existing technology. Continuous innovation tends to provide a continuous improvement to some product (Eike, 2012). Discontinuous innovation generally refers to the breakthrough change when the existing technology can not meet user needs (Kallio *et al*., 2012). Discontinuous innovation often brings new-look product or technology and it is even revolutionary to the enterprises development (Tessitore *et al*., 2012). Therefore, discontinuous innovation is more important to a company or country (Wiseman and Anderson, 2012).

Although scholars have carried out research on discontinuous innovation for over 30 years, the concept has not been widely accepted so far. Compared to continuous innovation, discontinuous innovation is often based on breakthrough technologies and can change market structure significantly. They need to be distinguished with the relationship between technology and market.

Discontinuous innovation will endue products with new features and user can enjoy more use after consuming these products (Meyers and Tucker, 1989). Uncertainty of technology, market and time is widespread in discontinuous innovation (Lynn *et al*., 1996). Discontinuous innovation means that technology and market are discontinuous (Veryzer, 1998) and discontinuous innovation should be defined from technology and market (Garcia and Calantone, 2002). Discontinuous innovation product should have the following characteristics: New performance, performance improvement and cost reduce (Leifer *et al*., 2000). Uncertainty of discontinuous innovation can be divided into technological uncertainty, market uncertainty, resource uncertainty and organizational uncertainty.

Long-term technology development process of aviation, cement, personal computers and glass manufacturing have been researched and these conclusions have been obtained that the contribution rate of continuous innovation to technological progress is 19.55% and the contribution rate of discontinuous innovation to technological progress is 63.55% (Tushman and Anderson, 1986; Anderson and Tushman, 1990). History of technological development of 167

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semiconductor companies have been analyzed and the results of the analysis showed that discontinuous innovation could bring structural change to core competencies of the semiconductor industry and there is a close relationship between discontinuous innovation cycle and jump development of enterprise core competencies (Walsh *et al*., 2005). Development process of discontinuous innovation of computer industry have been studied and these results have been found that the speed of improvement of product improvement decide the time of discontinuous innovation appearing (Funk, 2008).

According to existing research of discontinuous innovation, the causes of discontinuous innovation can be divided into ten categories: shift of cultural attitudes, reform of management system and country's political system, shift of techno-economic paradigm, innovation of business model, accidents, adjustment of industrial structure, emergence of new markets and technologies, major changes of market sentiment (Bessant *et al*., 2005; Phillips *et al*., 2006a, b). Faced with these incentives, the enterprise should taken different levels of response measures including the coping behaviors of strategic level and organizational level.

In summary, discontinuous innovation has been committed to the definition, infection to technology and economic from the date of birth. Causes analysis of discontinuous innovation begins from 21st century, especially the relation between country's policy and discontinuous innovation is rarely discussed. In this paper, the role of science and technology policies for discontinuous innovation was researched according to the actual characteristics of Chinese national conditions. The economic mode of China is a market economy supplemented by the government macro-control. So the results of discontinuous innovation are impacted by government policies in large part. Science and technology policy, monetary policy, fiscal policy and tax policy has a direct or indirect influence for discontinuous innovation of China. In this paper, Beijing related data of science and technology policy and discontinuous innovation was taken as subjects of empirical research such as unit root test, cointegration analysis and empirical conclusion would be used in revealing the intrinsic relation between discontinuous innovation and science and technology policies of China.

SELECTION FOR SOURCE DATA AND VARIABLE

If relationship was directly extracted according to content of policy and discontinuous innovation, more subjective factors could be introduced. Therefore, specific data of technology policy and discontinuous innovation was selected and credible analysis tool was used in this study.

Variables selection of discontinuous innovation

Characteristics of discontinuous innovation: Innovation is the concept linking to technology progress, efficiency improvement and economic development which is particularly evident when innovation is contacted with enterprise development. Each company has some core technologies. Along with users' demands increase constantly, company can move forward relying on continuous progress of its core technology. The technology progress does not subvert the original design concept and the core framework and it is just some kinds of functional change and enrich. This is a forward and continuous improvements. So, it is called continuous innovation.

However, when a technology and its products reach saturation, continuous innovation will not meet the new demands of consumers. At this time, new technology invention or technology from other fields must be introduced and existing technology must be breakthrough.

Technology progress can be described by S-curve and discontinuous innovation can be described by deformation of the S-curve shown in Fig. 1.

In Fig. 1, continuous innovation was described by S-curve in XOY plane and discontinuous innovation was described by S-curve from ACB plane to XOY plane. S-curve of discontinuous innovation expresses that new invention or technology from other fields was needed. By comparing scope of two S-curves, we can find that discontinuous innovation has a breakthrough, creative or revolutionary effect to technology progress.

Variable of discontinuous innovation: Patent is the most direct description of innovation. However, discontinuous

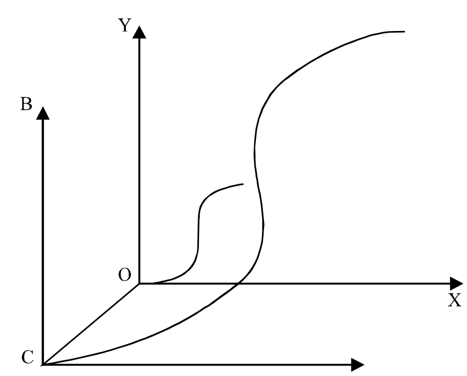

Fig. 1: S-curve of discontinuous innovation

Table 1: Statistical data of TP, RF, NIP, LTP, LRF and LNIP

Year	TP	RF	NIP	LTP	LRF	LNIP
1996	265552	418614	246	12.48956596	12.94470453	5.505331536
1997	273161	532257	281	12.51781664	13.18488173	5.638354669
1998	237127	861138	309	12.37635114	13.66601005	5.733341277
1999	229584	938437	573	12.34402425	13.7519710	6.350885717
2000	261113	1557011	1074	12.47270854	14.25827852	6.979145275
2001	240609	1711696	946	12.39092849	14.35299525	6.852242569
2002	257326	2195402	1061	12.45809904	14.60187573	6.966967139
2003	270921	2562518	2261	12.50958254	14.75650093	7.723562472
2004	301202	3169064	3216	12.61553641	14.96894683	8.075893630
2005	383153	3795450	3476	12.85618967	15.14931354	8.153637486
2006	382756	4329878	3864	12.85515299	15.28104992	8.259458195
2007	450331	5270591	4824	13.01773815	15.47765306	8.481358738
2008	450147	6200983	6478	13.01732948	15.64021839	8.776167100
2009	529985	6686351	9157	13.18060398	15.71557884	9.122273893
2010	529811	8218234	11209	13.18027562	15.92186590	9.324472306

In Table 1, TP, RF and NIP were used in expressing technology personnel investment, research funding investment and the number of invention patent of Beijing from 1996 to 2010. LTP, LRF and LNIP are the results of logarithmic operations for TP, RF and NIP

innovation is so breakthrough that general patent is not enough to become a credible description. In a study where breakthrough innovation was researched about biotech industry of USA, patent with high citation is used in characterizing discontinuous innovation (Phene *et al*., 2006).

Compared to the United States, the definition of the types of patents are different in China. Chinese patents are explicitly divided into three categories: invention patents, utility models and exterior design. Among these patents, the audit of the invention patent is extremely rigorous and they could be used in characterizing discontinuous innovation of China. Citation times of patents have not been track record in China. So, the number of invention patent was taken as discontinuous innovation of Beijing which is denoted by NIP in this study.

Variables selection of science and technology policy: Many policies of a country have direct or indirect impact on discontinuous innovation. China is the representation of national macro-economic control system and many policies of China has guiding role for the development of some fields. In China, science and technology policy, monetary policy, fiscal policy and tax policy all have impact on discontinuous innovation and the most direct one is science and technology policy. In this paper, relevant data in the Beijing Statistical Information Net has been selected as the basic data of empirical analysis. Data of science and technology policy was taken as final data of empirical analysis because investment of financial policy, fiscal policy, tax policy is not specific to discontinuous innovation.

Research and development (R and D) data is the most direct expression which support development of innovation in the Beijing Statistical Information Net. R and D data can be further divided into two groups: technology personnel investment and research funding investment. These two variables are denoted as TP and RF, respectively in this study.

DATA SOURCE

The number of invention patent, technology personnel and research funding had been selected from 1996 to 2010 and they are expressed by the abbreviation of NIP, TP and RF respectively. To eliminate the effects of heteroscedasticity during empirical analysis, these three variables had been carried out logarithmic operation. Then three new variables generated just like LNIP, LTP and LRF. All data are listed in Table 1.

In order to observe three sets of experimental data, histogram of the data in Table 1 is shown as Fig. 1.

EMPIRICAL ANALYSIS

Eviews is the most successful software of judging the relationship of time-series data. Therefore, Eviews was taken as the processing platform to carry out the cointegration test between discontinuous innovation and Beijing technology policy.

Unit root test: First, the time series of variable was carried out stationarity test in order to avoid spurious regression. Each variable need implement unit root test by ADF test and the basic principle is as follows:

ADF model includes three forms: with constant item and linear time trend item, with constant item and without linear time trend item, without constant item and linear time trend item. The mathematical models are as follows:

$$\Delta y_t = \varphi y_{t-1} + \sum_{i=1}^{p} \eta_i \Delta y_{t-1} + \varepsilon_t \quad (1)$$

Table 2: Analysis of unit root test for three variables (LTP, LRF and LNIP)

Series	Statistic test value	1% critical value	5% critical value	10% critical value	Probability
LTP	0.733629	-4.0681	-3.1222	-2.7042	0.685297
LRF	-1.429889	-4.0681	-3.1222	-2.7042	0.560109
LNIP	-0.818827	-4.0681	-3.1222	-2.7042	0.722239
D(LTP)	-2.171628	-4.1366	-3.1483	-2.7180	0.004030
D(LRF)	-2.303857	-4.1366	-3.1483	-2.7180	0.000041
D(LNIP)	-2.798751	-4.1366	-3.1483	-2.7180	0.000265
D(LTP, 2)	-4.367943	-4.2207	-3.1801	-2.7349	0.000142
D(LRF, 2)	-6.249776	-4.2207	-3.1801	-2.7349	0.000000
D(LNIP, 2)	-7.994824	-4.2207	-3.1801	-2.7349	0.000126

In Table 2, unit root test is used in testing the stationarity of time series and it is also the basis for cointegration test preparation

Table 3: Results of Johansen test

Hypothesized No. of CE (s)	Eigenvalue	Statistic (Trace)	Critical value (0.05)	Probability
Unrestricted cointegration rank test (Trace)				
None *	0.979728	78.24009	29.79707	0.0000
At most 1	0.856911	27.55919	35.49471	0.0005
At most 2	0.161088	2.283442	3.841466	0.1308
Unrestricted cointegration rank test (Maximum eigenvalue)				
None**	0.979728	50.68089	21.13162	0.0000
At most 1	0.856911	25.27575	34.26460	0.0006
At most 2	0.161088	2.283442	3.841466	0.1308

Trace test indicates 1 cointegrating at the 0.05 level, Max-eigenvalue test indicates 1 cointegrating at the 0.05 level, *Denotes rejection of the hypothesis at the 0.05 level

$$\Delta y_t = \alpha + \varphi y_{t-1} + \sum_{i=1}^{p} \eta_i \Delta y_{t-1} + \varepsilon_t \quad (2)$$

$$\Delta y_t = \alpha + \beta t + \varphi y_{t-1} + \sum_{i=1}^{p} \eta_i \Delta y_{t-1} + \varepsilon_t \quad (3)$$

where, y_t is a variable of time series, Δy_t it the first difference of y_t, α is the constant item, β is the time trend item, η_i is the difference coefficient of y_t for different lag, ε_t is random error term.

MacKinnon critical value need be used in judging whether there is one unit root for time series. If ADF statistics value is bigger than MacKinnon critical value, there is one unit root for time series y_t and y_t is a non-stationary series. Otherwise, y_t is a stationary series. By using the data in Table 1, the results of ADF test are shown in Table 2.

In Table 2, these three groups of variables turned into a stationarity series after a second-order difference. The results show that these three variables meet the conditions of cointegration test.

Cointegration test: Cointegration test is a measure whether there is a long-term relationship among several sets of time series data. Johansen test method is used in this study (Feng and Chen, 2010). And this method can obtain two types of results: Track inspection result and the largest characteristic root result. By using the data in Table 1, the results of Johansen test are shown in Table 3.

From Table 3, we can see that there is one cointegration relationship among these three variables TP, RF and NIP. This indicates that there is a long-term equilibrium relationship among the number of invention patent, the number of technology personnel and the research funding in Beijing. After further test, this relationship is shown as formula (4):

$$\begin{aligned} LNIP = 0.697502LTP&+1.156250LRF-18.31770 \\ (0.323771)\quad&(0.104102) \end{aligned} \quad (4)$$

According to formula (4), LTP, LRF and LNIP are positive correlation in a long time. When LTP increases 1%, LNIP will increase 0.70%. When LRF increases 1%, LNIP will increase 1.16%.

DISCUSSION OF EMPIRICAL RESULTS

Empirical research literature is few about discontinuous innovation and the research paper is even less about discontinuous innovation affected by the policy of a region or a country. Therefore, the empirical results in this study can not be compared with existing research results.

Here, we can only discuss some research results about policy, innovation and discontinuous innovation:

- Phene *et al*. (2006) studied breakthrough innovations of the US biotechnology industry and draw a conclusion that technologically distant knowledge of national origin has a curvilinear effect and technologically proximate knowledge of international origin has a positive effect on breakthrough innovation (Phene *et al*., 2006).

- Di Benedetto *et al*. (2008) carried out empirical analysis by using data of US, Japan and China and found that there is an evident and positive relation between information technology capabilities and radical product innovation
- Song and Thieme (2009) confirmed that discontinuous innovation has a considerable positive impact on market intelligent
- Wang and Xiao (2011) found that there is a two-way influence between discontinuous innovation and modular of Chinese vehicle industry
- Paraskevopoulou (2012) considered that public policy can not directly affect the discontinuous innovation but have the potential to promote innovation development
- Matus *et al*. (2012) found that discontinuous innovation encountered obstacles in China's green chemical industry and policy need to be introduced
- Costantini and Mazzanti (2012) confirmed that policy and innovation can promote industrial energy efficient operation
- Li and Yunke (2012) found that China's environmental policy is not enough to support scientific and technological innovation

Although, there are many researches on discontinuous innovation, the data and methods are not the same to the research in this study. So a direct comparison can not be formed between this paper and appeared literature.

Here, we will further have to analyze the empirical results obtained in this study. From the point of view on the empirical analysis and results, a positive correlation does exist between discontinuous innovation and science and technology policy of Beijing. In other words, science and technology policy support has played a positive role in promoting the discontinuous innovation of Beijing. By empirical analysis of data nearly 15 years, we can see that the number of discontinuous innovation will increase 0.7% when the number of scientific and technical personnel increase 1% and discontinuous innovation will increase 1.16% when the number of research fund increase 1%. This quantitative conclusion is consistent with the qualitative relationship between discontinuous innovation and science and technology policy. The empirical results also show that more support of science and technology policy is needed in order to improve the ability of discontinuous innovation of Beijing such as investing more researchers and research funding.

CONCLUSION

Characteristic variable of technology policy and discontinuous innovation had been taken as experimental data and the Number of Invention Patent (NIP) was denoted discontinuous innovation and the number of Technology Personnel (TP) and Research Funding (RF) was denoted technology policy. Then ADF test and Johansen test had been implemented by using Eviews software. According to the results of ADF test, we can find that these three variables meet the conditions of cointegration test. The results of Johansen cointegration test show that LTP, LRF and LNIP are positive correlation in a long time. When LTP increases 1%, LNIP will increase 0.70%. When LRF increases 1%, LNIP will increase 1.16%. Test results tell us the fact that there is a long-term equilibrium relationship among the number of invention patent, the number of technology personnel and the research funding in Beijing. And this correlation is positive which reveals the rules that discontinuous innovation was promoted by science and technology policy.

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