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Hysteresis Effects of R&D Expenditures and Patents on Firm Performance: An empirical study of Hsinchu Science Park in Taiwan

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Abstract. R&D expenditures and patents are important means to improve an enterprises capacity in technological innovation, and are also drivers for sustainable development of a country. This study investigated R&D expenditures, patent quantity and performance of the top six industries in Taiwans Hsinchu Science Park for the period of 1988-2011. VAR model was used to analyze the relationship between R&D expenditures, patent and performance, and the hysteresis effect. The results showed that the governments R&D expenditures and patent quantity have a long-term and stable relationship with performance, as well as a positive correlation with performance, and a hysteresis effect on performance. The hysteresis effect of R&D expenditures and patents on performance is significantly different in different industries. These findings suggest that the governments R&D expenditures can bring economic effects to enterprises and improve enterprises innovation capacity. Thus, both government and enterprises should attach importance to R&D expenditures.

1. Introduction

Technological rapidly changes have causing operation environment uncertainty, especially in high-tech industries. To reflect the turbulence environment, the R&D expenditures as a key drive force to increase innovation deployment and to maintain sustainable development of the firms. There are many researchers had pointed out that the R&D expenditures not only have positive impact on the productivity growth and economic performance but also have a significantly positive effect on the future firm value [1, 2]. Furthermore, some researcher also found that huge R&D expenditures cannot maintain innovative performance and firms competitiveness. Markides (1999) [3] considered continuous R&D expenditures may cause enterprises to confront with high costs and uncertain risks and R&D expenditures have hysteresis effect [4–7]. Jaffe (2000) [8] found that R&D expenditures and patent application have no hysteresis effect, and hysteresis effect cannot significantly affect research conclusions [9]. Currently, Taiwans technologies are sourced from the U.S. and Japan [10]. The enterprises are facing great challenges posed by transformation. The Science Park adopts R&D expenditures and patent as an innovation policy, which has attracted high attention from the government, enterprises and academia. R&D expenditures as a new innovation policy

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are controversial. It is urgent to explore whether R&D expenditures and patents can affect firm performance or have hysteresis effect.

Economists generally use R&D expenditures and patents as approximate indicators to measure innovation input-output. Continuous increase of earnings and profits is used as the final output [11, 12]. Dosi (1993) [13] used patents to analyze the innovation input-output in earlier time, and conducted a quantitative research on patent and R&D. Many scholars studied patents in the 1980s. Patent data has played an increasingly important role in innovation analysis [14]. Many studies have shown that patents have a positive effect on corporate performance [15, 16]. Ernst et al. (2000) [17] used the effect of patent output on corporate earnings to determine the adjustments necessary for R&D departments. Cohen et al. (2002) [18] compared the patent policies between the U.S. and Japan, as well as the effect of R&D on companies. Ernst (2003) [19] used patent indicators to monitor activities of competitors, R&D management and HR management. Furman et al. (2002) [20] suggested that patents as an innovation output has limitations, and differences in industries, regions, and periods would result in different tendencies towards patents [9]. Not all inventions by enterprises can obtain patents, and not all innovations can be used to apply for patents. Different patents have different characteristics, thus, varied economic efficiency. Most countries and enterprises consider patent as a reliable indicator of evaluating innovation [9, 12]. Thus, discussion on the relationship between R&D expenditures and patents, as well as the effect of patents on enterprises, can help enterprises making decisions and promoting enterprise innovation. In early time, R&D expenditures and patent innovation were mainly concentrated in developed Western countries. The hysteresis effect of R&D expenditures was discussed from the perspectives of R&D expenditures and output, as well as R&D expenditure and performance. Most studies were focused on the influence of R&D of high-tech industries, listed companies and large enterprises on the operational performance. Due to limitations to data sources and samples, small samples were selected for research. The research results were disputable, and the research results on R&D expenditures, patents and hysteresis effect of performance were not consistent and controversial. Meanwhile, the effect of R&D expenditures as the new innovation policy by government in science parks, and whether it has a hysteresis effect should be further discussed and demonstrated. This study applied pulse response analysis of VAR (Vector Auto Regression) model to identify the relationship between R&D expenditures, patent output and performance, and hysteresis effect. The VAR model based on longitudinal data makes up the deficiencies in the method of exploring hysteresis effect of R&D expenditures and sample data. Rindfleisch et al. (2008) [21] suggested that the cause-and-effect relationship can be supported by research based on the longitudinal data. The remainder of this paper is organized as follows. Section 2 presents literature review on R&D expenditures, patents and operating performance; Section 3 introduces the research design, modeling, sample source, and variable description and statistical tools; Section 4 investigates the samples of Hsinchu Science Park, and VAR is used to analyze R&D expenditures, patents and hysteresis effect of performance; Section 5 offers conclusions and suggestions.

2. Methodology

2.1. R&D expenditures

R&D is an important factor affecting innovation [22]. Enterprises create new products or services through R&D, and thus, earn more profits. R&D expenditures include tangible expenses, personnel and equipment, and intellectual assets. The R&D expenses are often used as an important variable to measure innovation and performance [23, 24]. Output of R&D activities requires a series of conversion behaviors. R&D expenditures have a positive correlation with operating performance [25], and R&D expenditures have a hysteresis effect on profitability of enterprises [4, 5, 7]. Sharma & Thomas (2008) [26] argued that the hysteresis effect of national R&D activities on high-tech industries lasts for two years. Fre et al. (2008) [27] found that the hysteresis effect of R&D on the U.S. agriculture lasts for four to ten years. Hashimoto and Haneda (2008) [5] suggested that the hysteresis effect of R&D on pharmaceutical industry lasts for eight years. Guan and Chen (2010) [28] found that the hysteresis effect of R&D expenditures and output lasts for two years, based on the samples from 30 Chinese provinces. Lu et al. (2006) [29] selected Taiwanese electrics companies as the subjects, and found that the hysteresis effect of R&D on productivity lasts for

one year. Wang and Wu (2012) [30], and Huang and Hsu (2014) [31] found that the hysteresis effect of R&D of integrated circuits on output lasts for two years, and that on operating performance lasts for one year (Figure 1). Thus, the R&D expenses can be used as input variable of evaluating operating efficiency of high-tech industries [32].

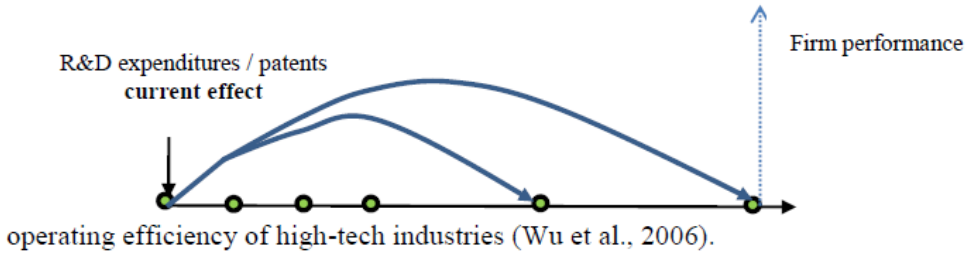

Figure 1: R&D expenditures, patents and firm performance of the hysteresis effect

2.2. Patents

Patent is an intellectual property right granted to an inventor in accordance to law, and can be used to promote industrial development and inventions. Patent quantity in this paper refers to the number of patents applied by the science parks, and approved by the Intellectual Property Office, Ministry of Economic Affairs. There are three types of patents: invention patents, utility patents, and design patents. A patentee has the right to stop any imitation, copy, sales, use and other infringement act, as well as claim for indemnities and monopolize the market within a certain period of time to maintain competitiveness. Teece (1998) [33] indicated that intangible assets such as know-how, R&D and patents can improve competitiveness and operating performance. Trappey and Trappey (2008) [34] found that patents can protect R&D results of companies, and be used as an effective tool to attack rivals. Acs and Audretsch (1987) [35] used patents as output of R&D. Patents can be used to measure know-how and innovation energy, and may affect company performance [24, 32]. Deng et al (1999) [36] discussed innovation and R&D, and found that the number of approved patents, times of patent citations, and number of patent rights citations in academic papers, can be used to predict the future stock returns and market values of enterprises. Moreover, patent is an important evaluation indicator of R&D input and output [26, 37], but it requires an average of two years of R&D input for obtaining patents. Patents have a hysteresis effect on enterprise efficiency [19]. Ken & Tsai (2010) [38] investigated the U.S. pharmacy industry, and found that patents have a significant impact on earnings per share, and the hysteresis effect lasts for four years. As an innovation strategy, successful application of patent can facilitate technical change through innovation [39]. Thus, R&D patents and other intellectual assets should be managed scientifically [23, 24].

2.3. Performance

Performance is an important indicator of competitiveness, and also a topical subject in academia. Many countries have attempted to evaluate the success of a science park by observing whether it promotes regional economic growth and the contribution to GDP. Performance of the science park is affected by various factors, including total business turnover. The administrative performance of the park includes aspects of planning and preparation, management system, service system and organization performance. Hence, the total business turnover is a straightforward indicator to evaluate performance [32]. The total business turnover refers to net sales of the manufacturers in the park (including sales in the declaration, total of receipt notes, sales return and discounts, and sales adjustment of previous period) minus accumulation of deductible items (bill collection, sales of fixed assets, sales of wastes, income of interests, presentation of gifts). This study used the total business turnover of enterprises in the science park as an output variable to evaluate the park performance.

2.4. Research model

This study used impulse response function of the VAR model to analyze R&D expenditures, patents and hysteresis effect of business performance. Each endogenous variable in the system is used as a function of lagged value of endogenous variable in the system for model construction. The VAR model proposed by Sims (1980) [40] is commonly used in economics study, particularly the dynamic analysis of economic system. VAR can be used to predict associated time series systems and analyze the dynamic impact of stochastic disturbance on a variable system. This can explain the influence of various economic shocks on economic variables [41]. Ltkepohl (1993) [42] suggested that the VAR model can be used to analyze the dynamic impact of variables in a system, the long-term impact of variables, and further prevent variables deficiency and solve error in the endogenous variable. The econometric model equation is as follows:

$$LnFP_t = B_0 + \sum_{p=1}^{k} \theta_{11p}(LnFP_{t-p}) + \sum_{p=1}^{k} \theta_{12p}(LnR\&D_{t-p}) + \sum_{p=1}^{k} \theta_{13p}(LnPQ_{t-p}) + \epsilon_{1t}$$

Where the dependent variable FP is park performance, R&D is R&D expenditures, PQ is patent quantity,B_0 is estimated coefficient, t is time, and ϵ is constant. All variables take the logarithm Ln.

2.5. Variable description

Business turnover of the science park is used as performance evaluation indicator, and is denoted by dependent variable Y. The R&D expenses associated with the operation management and patent quantity are denoted by independent variable X. The operational definitions of the variables are shown in Table 1. The industrial structure is a controlled variable. Different industries have significant differences in performance. The impact of industrial environment factors on enterprise performance should be controlled. The analyzed samples are selected from the same park with high homogeneousity [43–45]. The industrial structure discussed in this paper includes six major industries in the park, namely integrated circuits, computer peripherals, communications, photoelectricity, precision machines and biotechnologies.

Table 1: Definitions of research variables

Currency: NTD

Variable	Description	Unit	Measurement method
Ln(R&D)	R&D expenditures	Million	Refer to R&D expenditures, subject to survey results of technical statistics of the National Science Council.
Ln(PQ)	Patents	piece	Refer to the number of patents filed by the manufacturers, and approved by the Intellectual Property Office, Ministry of Economic Affairs.
Ln(FP)	Total business turnover	0.1 billion	Refer to the total net sales of the manufacturers in the park.

2.6. Sample selection and data source

Founded in 1980, the Hsinchu Science Park in Taiwan was planned, constructed and managed by the Ministry of Science and Technology. The purpose of the park is to build a people-friendly environment to for high-quality R&D, production, work and leisure, cultivation of high-tech talents, introduction of high technologies, constructing a high-tech industry base, and promoting the industrial upgrading and economic development. The Hsinchu Science Park plays an important role in high-tech development and technical innovation, serving as a new policy to promote national or regional economic development [46]. Through R&D expenditures, the government promotes enterprises to maintain sustainable R&D expenditures to foster their R&D strengths. In earlier time, the manufacturers in the park were engaged in OEM, and the park successfully brought together global semi-conductor manufacturers. By the end of 2012, there were 485 high-tech enterprises in the Hsinchu Science Park. The major industries include

semiconductors, computers and peripherals, communications, photoelectricity, precision machineries and biotechnology. The industrial paid-up capitals reached 1000 billion NTD; the R&D expenditures were 40 billion NTD, patent quantity reached 3000, and the total business turnover was 1000 billion NTD. The park has technological advantages and abundant advanced knowledge, thereby directly or indirectly excelling Taiwans high-tech industry, forming the integrated supply chain, and making a great contribution to the high-tech industry. The research data were collected from Hsinchu Science Park website, the database of the Ministry of Science and Technology, and the website of the Directorate General of Budget, Accounting and Statistics. The park was founded in 1980, hence, there was no business turnover during the infrastructure construction periods of 1981 and 1982. The data of 1983-1987 were not complete due to management system and statistics gathering problems. Thus, the annual data of 24 years between 1988 and 2011 were selected as research data. To eliminate heteroscedasticity, natural logarithmic transformation was conducted for the data, as shown in Figure 2.

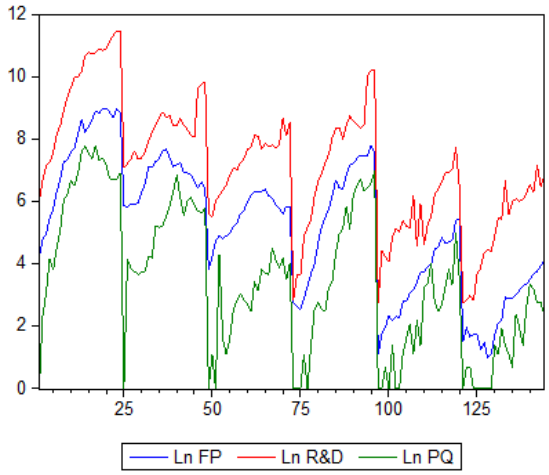

Figure 2: Data relation between R&D expenditures, patents and performance

2.7. Statistical analysis method

This study used EViews6.0 software for data stability analysis, cointegration test and Granger causality analysis. The impulse response function analysis was conducted to verify the hysteresis effect of R&D expenditures and patents on performance.

3. Results

3.1. Variable balance test

This study used ADF (Augmented Dickey Fuller Test) proposed by Said & Dickey (1984) [47] to verify variable stability. The results are shown in Table 2. The optimum hysteresis period was determined by minimum error criteria of AIC (Akaike information criterion) [41, 48] to ensure none autocorrelation of residual errors. As shown in Table 2, only performance is not stable among the variables at a significance level of 0.05, and is stable at a significance level of 0.05 after difference sequence. This suggests that R&D expenditures have hysteresis quality. Some studies suggest that the hysteresis effect of technology input and output lasts for two years [26, 28, 30], while other argue that the hysteresis effect lasts for three to five years [5, 7, 27]. Moreover, obtaining patents has a longer hysteresis effect period. After the test using ADF method, the variable stability has second-order lag; hence, the impact of R&D capital stock is eliminated to a great extent.

Table 2: Results of unit root test

Variable	Test type (c, T, d)	ADF statistics	t statistical value	Adjoint probability P	Conclusion
Ln FP	(c, T, 1)	-2.285880	-2.881685	0.1780	Instable
D (Ln FP)	(c, 0, 0)	-0.071675	-2.285880**	0.0238	Stable
Ln R&D	(c, 0, 0)	-3.330265	-2.881685	0.0153	Stable
D (Ln R&D)	(c, 0, 0)	-0.144803	-3.330265**	0.0011	Stable
Ln PQ	(c, 0, 0)	-2.892095	-2.881830	0.0488	Instable
D (Ln PQ)	(c, 0, 1)	-0.140739	-2.892095**	0.0044	Stable

Note: (c, T, d) separately stand for intercept, time trend and lag order of the equation in the test; the lag order is determined by using SC minimum error criteria; D (X) is Xs first order difference; *, ** and *** mean refusal of null hypothesis at significance level of 10%, 5%, and 1%.

As shown in Table 3, times series of individual variables is not stable. Thus, the cointegration test proposed by Johansen (1995) [49] is used to test whether linearity of these unstable variables has stable time series, and to identify long-term balance relationship between these variables. The results are substituted into the cointegration equation as follows:

$$FP_t = \text{-}2.0323\ Ln\_R\&D + 0.8356\ Ln\_PQ$$

$$(0.3539) \qquad (0.3156)$$

According to the cointegration equation, Figure 1 shows that the performance FP of the science park has a long-term balanced relationship between R&D expenditures and patent quantity. Performance has a significantly positive correlation with R&D expenditures and patent quantity. In other words, the performance of the science park may be improved with increased R&D expenditures and patent quantity.

The unit root test and the cointegration test show that R&D expenditures and patents have a long-term stable relationship with performance, and cannot explain the economic causality existing between the variables. Thus, Granger causality analysis is performed. As Figure 3 indicates, reciprocal of all characteristic roots of variables is located in the circle, and should be less than 1. This proves that the VAR model is stable, and other variables change when some variables in the VAR model change. This influence may disappear over time. It has been demonstrated that the economic system consisting of government's R&D expenditures, patents and performance in the science park is stable.

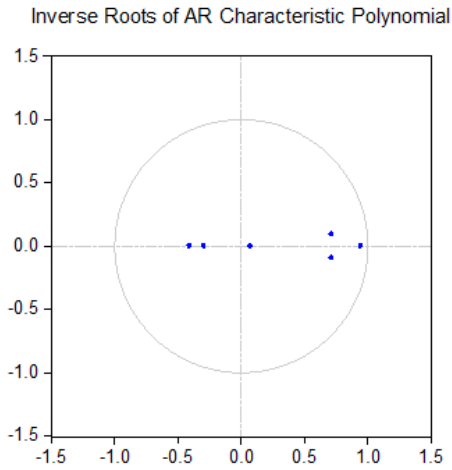

Figure 3: Inverse roots of AR characteristic polynomial

3.2. Impulse response function analysis

The impulse response function of the VAR model is used to analyze the hysteresis effect of R&D expenditures and patents on the performance of the Hsinchu Science Park (Figures 4 to 6). The horizontal axis in the figure is the hysteresis effect period of the impulse, which is 10 periods; the vertical axis is impulse response function, and indicates the response of dependent variable to independent variable. The blue solid line is the path of the impulse response function, and the two red dotted lines is the confidence belt which is two times standard deviation.

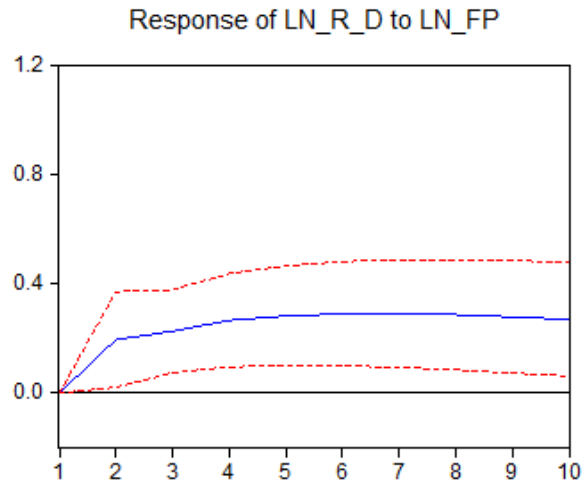

Figure 4: Response of R&D to FP

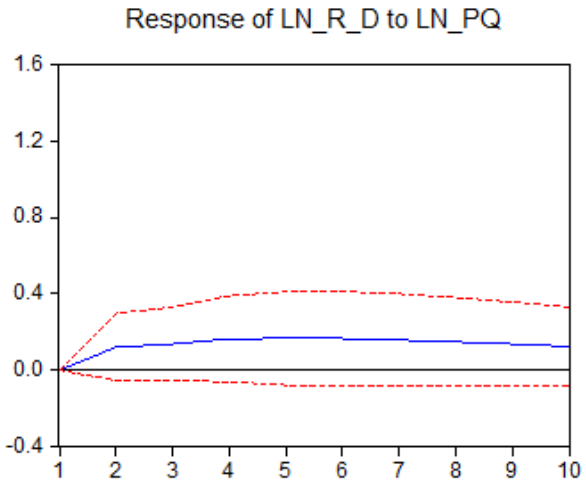

Figure 5: Response of R&D to FP

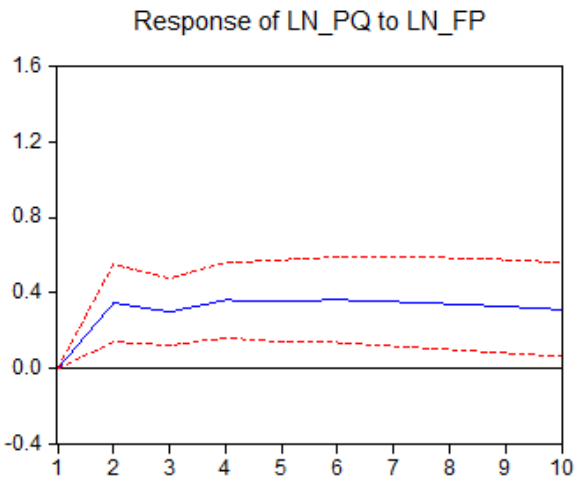

Figure 6: Response of PQ to FP

Figure 4 shows that R&D has a positive impulse response to performance. The impulse response continuously increases in the second period, and is stably converged in the sixth period. The convergence tends to decrease in the ninth period. Figure 5 shows a positive response function of R&D to patent quantity. The function continuously increases in the second period, reaches the highest positive response point in the fifth period, and then becomes stable. The convergence tends to decrease in the eighth period. Figure 6 shows the positive response function of patent quantity to performance. It slightly decreases in the second period, reaches the highest positive response point in the fourth period, and then become stable. The convergence tends to decrease in the ninth period. The science park used R&D expenditures as a new policy, which has a hysteresis effect on patents and performance, while patents also have a continuous hysteresis effect on performance.

4. Discussion

The R&D expenditures and patents in different industries are varied [9, 20]. The impulse response function of the VAR model is used to analyze the hysteresis effect of R&D expenditures on patents and performance in the six industries (i.e., integrated circuits, computer peripherals, communications, photo-electricity, precision machinery and biotechnology), as shown in Figures 7 to 12.

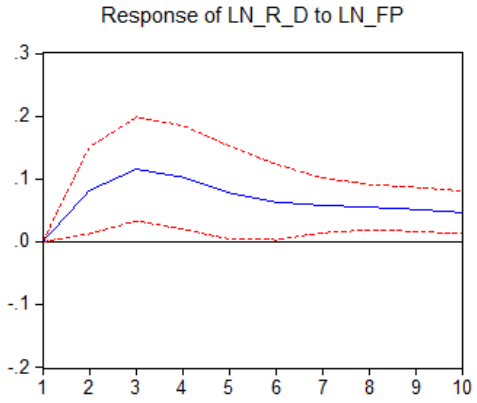

Figure 7: Response of hysteresis effect of R&D expenditures and patents to FP in integrated circuit industry

Integrated circuit is the largest industry in the Hsinchu Science Park, as well as an important emerging industry. The industry has rapidly upgraded technologies, thus sustaining a leading position in IC design, process material and wafer sealing. Integrated circuits are the key components and accessory parts of computers, communications and other consumer electronic products. As shown in Figure 7, R&D of the IC industry has a positive impulse response to performance. The response increases in the second period, then slowly decreases after reaching the highest point in the third period, and converges stably in the sixth period. The positive impulse response of R&D to patent increases continuously in the second period, and then reaches the highest point in the sixth period. It becomes stable and tends to converge in the eighth period. The positive impulse response of the patent to performance decreases quickly in the second period, and becomes stable in the fourth period after reaching the zero point. It becomes negative response in the seventh period, and slowly converges when it is closed to zero point. In other words, the hysteresis effect of R&D expenditures of the IC industry on performance reaches the peak in the third period, and has a long-term hysteresis effect on patent quantity. However, the hysteresis effect on patents disappears after reaching the peak in the second period. Thus, the IC industry should sustain R&D expenditures to improve performance, while paying attention to the risks of R&D expenditures upon the life cycle of high-tech products.

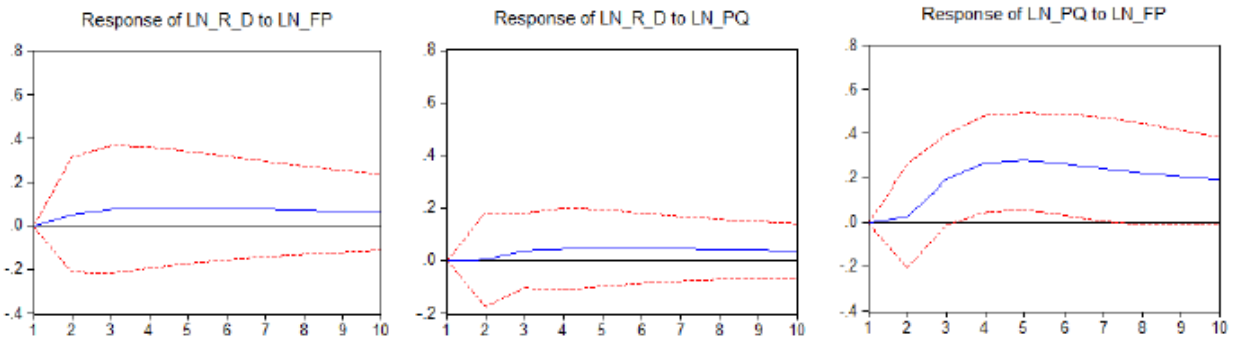

Figure 8: Response of hysteresis effect of R&D expenditures and patents to FP in optoelectronics industry

The opto-electronics industry, as Taiwan's core industry, is the second largest industry of the Hsinchu Science Park, and rivals against Japan and South Korea. It has sufficient R&D capacity and intellectual property protection system. Most of the enterprises in this study are of small and medium size, with high technical barriers. As shown in Figure 8, the positive impulse response of R&D of the opto-electronics industry to performance starts to increase in the second period, then becomes stable after reaching the peak in the fourth period, and converges stably after the sixth period. The positive impulse response of R&D to patents starts to increase continuously in the second period, then reaches the peak in the fourth period, and tends to slight converge after becoming stable in the seventh period. The positive impulse response of patents to performance increases rapidly in the second period, and reaches the peak in the fifth period. It starts to decrease and converges slowly in the sixth period. This indicates that the hysteresis effect of R&D expenditures on performance reaches the peak in the fourth period, and R&D expenditures have a long-term hysteresis effect on patent quantity in the opto-electronics industry. Furthermore, performance can be improved continuously through the hysteresis effect of patents. Thus, the opto-electronics industry should sustain R&D expenditures to improve performance, while paying attention to the risks of R&D expenditures upon the life cycle of high-tech products.

Computers and peripherals industry is the third largest industry of the Hsinchu Science Park. Most manufacturers are engaged in factory-assembled exports, and their main products are tablet PC, servers, and embedded touch screens. These enterprises have weaker R&D capacity. As seen in Figure 9, the positive impulse response of R&D of the computers and peripherals industry to performance maintains at the zero point. The positive impulse response of R&D to patent increases continuously in the second period and becomes stable after reaching the peak in the fourth period. It then decreases slowly and tends

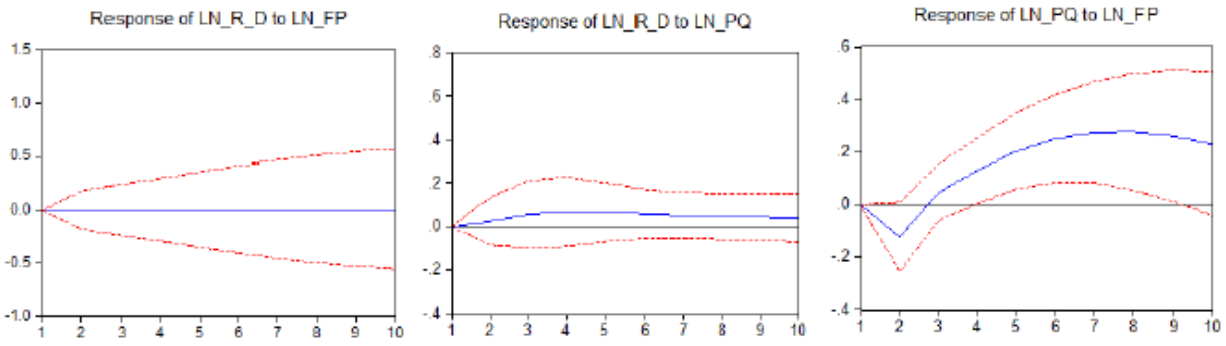

Figure 9: Response of hysteresis effect of R&D expenditures and patents to performance in computers and peripherals industry

to converge in the fifth period. The positive impulse response of patents to performance decreases to a negative responses lowest point in the second period, and starts to rapidly increase in the third period. It then reaches the peak in the seventh period, slightly decreases, and tends to converge in the eighth period. This means that the R&D of the computers and peripherals industry has no hysteresis effect on performance but has a long-term hysteresis effect on patent quantity. The patents have a hysteresis effect at first, followed by a long-term hysteresis effect. Although performance in the computers and peripherals industry cannot be directly improved by R&D expenditures, it can be improved through patents and improvement of technical strengths over the long run.

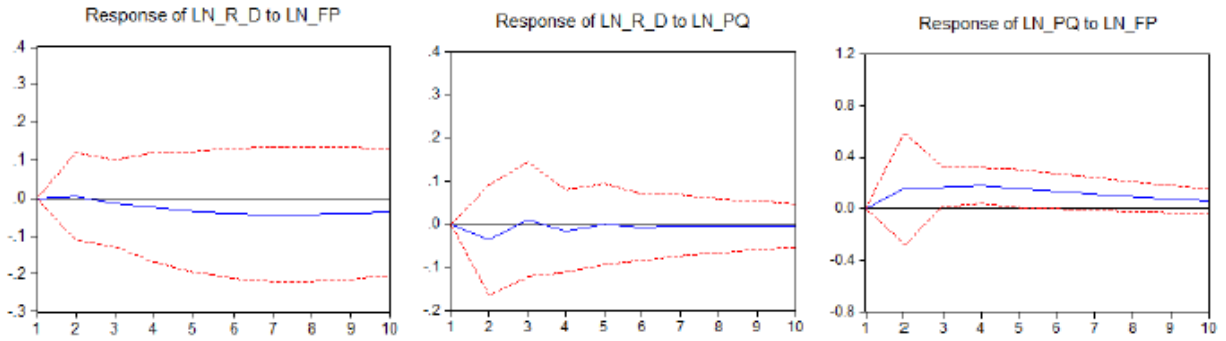

Figure 10: Response of hysteresis effect of R&D expenditures and patents to FP in communications industry

The communications industry is the fourth largest industry in the Hsinchu Science Park. Taiwans communications industry has a leading position in the world, with 90% of communications products assembled in Taiwan. As shown in Figure 10, the R&D of the communications industry to performance slowly decreases from zero point in the second period, and converges stably in the sixth period. It becomes a negative response, decreases and converges in the eighth period. The positive impulse response of R&D to patents decreases to negative response in the second period and rapidly reaches the peak in the third period. It then decreases to negative response from the third period to the fourth period. It increases to the zero point in the fifth period and then converges. The positive impulse response of the patents to performance continuously increases in the second period and reaches the peak in the third period. It becomes stable, and slightly decreases and tends to converge in the fifth period. This reveals that R&D expenditures of the communications industry have no hysteresis effect on performance, and has a long-term hysteresis effect on patent quantity. However, the hysteresis effect of patents can continuously improve performance. The performance of the communications industry cannot be directly improved by R&D expenditures, but can be improved through patents and enhanced technical strengths over the long run.

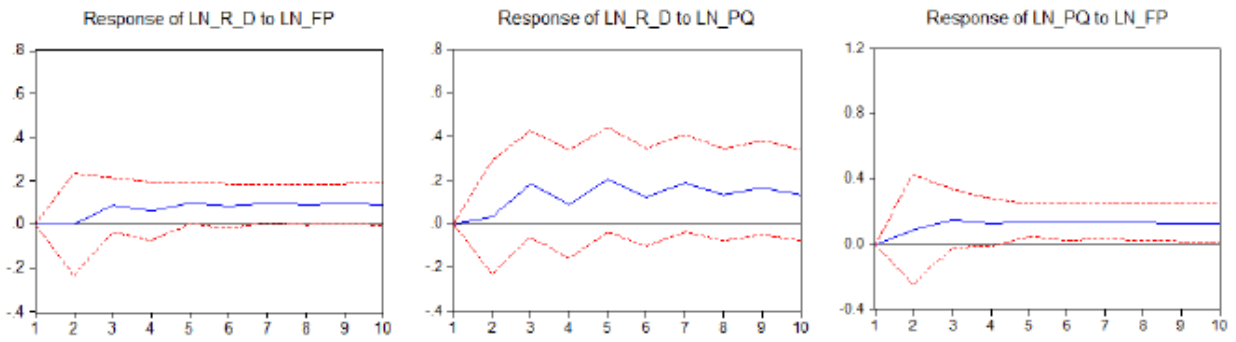

Figure 11: Response of hysteresis effect of R&D expenditures and patents to FPin precision machinery industry

The precision machinery industry is the fifth largest industry in the Hsinchu Science Park. As a backbone to the basic industries, it facilitates phased industrial upgrading. The precision machinery industry integrates high technologies, and specializes in design, analysis, simulation and manufacturing of precision equipment and systems, in order to improve production quality, efficiency and productivity of the precision machines. According to Figure 11, the positive impulse response of R&D of the precision machinery industry to performance starts to increase continuously in the second period, then reaches the highest point in the fifth period, and stably converges in the sixth period. The positive impulse response of R&D to patent starts to rise continuously from the second period and reaches the highest point in the third period. It continuously fluctuates, and slightly converges in the ninth period. The positive impulse response of patents to performance increases continuously in the third period, and slowly decreases and converges in the sixth period. This indicates that the hysteresis effect of R&D expenditures in the precision machine industry on performance reaches the peak in the fifth period, and the R&D expenditures have a fluctuant hysteresis effect on patent quantity. The performance can be increased by the hysteresis effect of patents. Thus, the precision machinery industry can improve performance through continuous R&D expenditures, and enhance the competitiveness through patents and elevated technical strengths. However, attention should be paid to risks of R&D expenditures upon the life cycle of high-tech products.

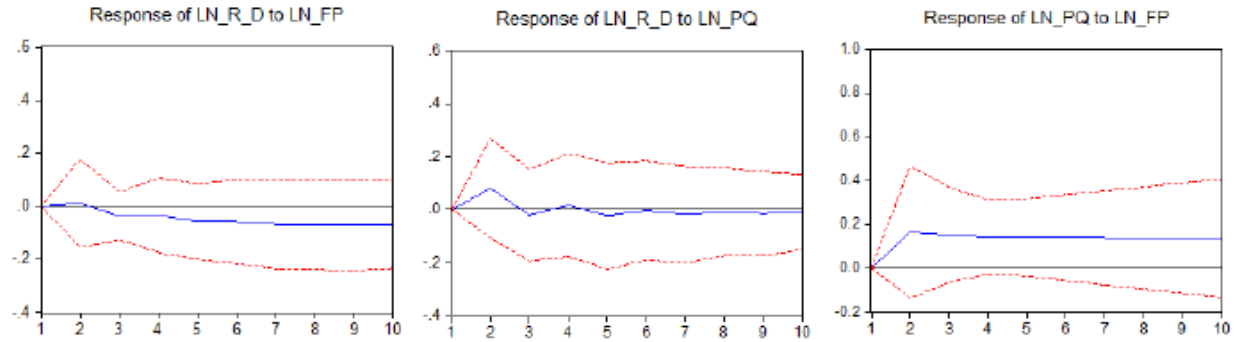

Figure 12: Response of hysteresis effect of R&D expenditures and patents toFP in biotechnology industry

The biotechnology industry is the sixth largest industry in the Hsinchu Science Park, as well as one of the top six emerging industries in Taiwan. It is a high-tech industry with high added value, low pollution and long product life cycle. The industry has an annual increase growth of 10%, and introduces patent technologies for re-innovation. As seen in Figure 12, the positive impulse response of R&D of the biotechnology industry to performance slowly decreases from zero point in the second period, and stably converges after the seventh period. It decreases to negative response in the eighth period and converges.

The positive impulse response of R&D to patent decreases from the positive response to the lowest point of the negative response between the second period and the third period, and then increases to positive response from the third period to the fourth period. It continuously fluctuates, and converges below zero point. The positive impulse response of the patents to performance becomes stable after reaching the highest point in the second period, and slightly decreases and converges after the seventh period. This reveals that the R&D expenditures of the biotechnology industry have no hysteresis effect on performance, and no significant hysteresis effect on the patent quantity. However, the hysteresis effect of patents can continuously increase performance. Although the performance of the biotechnology industry cannot be directly improved by R&D expenditures, it can be improved through patents and enhanced technical strengths over the long run.

5. Conclusion

This study investigated R&D expenditures, patents and performance data of the Hsinchu Science Park between 1988 and 2011. The impulse response function of VAR model was used to analyze the hysteresis effect of R&D expenditures and patents on performance. The empirical results showed that R&D expenditures and patents have a long-term and steady relationship with performance, and have a hysteresis effect on performance. These results are consistent with past findings [4, 5, 7, 35]. Moreover, it is found that the hysteresis effect lasts for two years, which is also consistent with the finding that the hysteresis effect period of high-tech industrial and national R&D innovation is two years [26, 28, 30], but differs from other studies that suggested the hysteresis effect period should be three and five years [5, 7, 27]. This inconsistency is attributed to difference in industries and samples. These results are consistent with the previous studies [9, 20, 45]. The R&D expenditures of the IC, opto-electronics, and precision machinery industries have a significant hysteresis effect on performance and patents. This finding is in line with the actual situations of the Hsinchu Science park. The R&D expenditures of the computers and peripherals, communications and biotechnology industries have no hysteresis effect on performance, and the performance can be improved by the patents and technology innovation strengths. This indicates that governments R&D expenditures can bring economic effect on enterprises, and both the government and enterprises should pay attention to R&D expenditures.

6. Recommendations

Taiwan is an export-oriented economic entity. The industrial development has shifted from labor intensive and capital intensive light industries to technology intensive high-tech industry. Due to the awareness of environmental protection and quality of life, biotechnology has become a star emerging industry in recent years, thus bringing changes to Taiwans high-tech industries. In the global market with high uncertainty, the government should initiate innovation measures, offer more incentive, and formulate preferential policies for innovation, in order to maintain innovation and promote economic development. The enterprises should establish innovative network connection, integrate internal and external resources, enhance innovation efficiency, and continuously improve innovative capacity, in order to elevate the competitiveness of enterprises. Due to the data source, there are certain limitations. Future studies can discuss the influence of governments R&D expenditures on social capital, and impact of enterprise scale and age on R&D expenditures, as well as differences in economic effect of different types of patents.

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