American export control, technology spillover and innovation of Chinese pharmaceutical Industry

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Abstract: This paper was aimed to analyze whether the U.S. strict export control to China affects the technological innovation of Chinese pharmaceutical industry. This paper selected the data of technological innovation and the expenditure of high and new technology adoption in China's pharmaceutical industry from 1995 to 2014, created panel regression model to study the impact of export controls on technology spillovers and the impact of technology spillovers on innovation capacity. The results show that US export control has a significant impact on technology spillovers, but foreign technology spillovers have no significant impact on the innovation of Chinese pharmaceutical industry. Although the US export control prevented foreign technology spillovers to China, but indirectly stimulated the domestic technology spillovers to pharmaceutical manufacturing industry in China. Statistical analysis show that the correlation coefficient between innovation capacity and expenditure for high technology adoption is not significant, but the expenditure of purchasing domestic technical is essential to pharmaceutical innovation. This study shows that US export control indirectly, not directly, affected the technological innovation of China's pharmaceutical industry, affected the allocation of innovative resources, but failed to prevent the technological progress and competitiveness improvement of Chinese pharmaceutical industry.

Keywords: Export control, technology spillovers, pharmaceutical industry, innovation capacity.

INTRODUCTION

It is the first time for Chinese pharmaceutical companies, Qilu Pharmaceutical Co., LTD., to export cephalosporin injection made in China to the United States in December of 2016. This has epoch-making significance for China's pharmaceutical industry (Hu *et al*., 2012). For a long time, China, as a large country, not a powerful country in pharmaceutical industry, has only been one of the raw material suppliers in the global pharmaceutical industry chain, 80% of pharmaceutical export is raw materials, the pharmaceutical preparation, as the high-end products of medicine industry, has been accounted for only about 10% (Belitz *et al*., 2016). The export structure began to change in 2012.The export of pharmaceutical preparation increased rapidly and the growth rate is higher than the overall pharmaceutical exports from 2012 through 2015. The pharmaceutical preparation export grew by 26.61% while the export of China's pharmaceutical exports fell by 0.92% during the first 8 months of 2016. China's pharmaceutical industry is undergoing tremendous changes, supply side reform and promote technological innovation is to become the main theme of the development of the country's thirteen five plan.

Changes in China's pharmaceutical export structure reflects the improvement of technological innovation capability and competitive in the pharmaceutical manufacturing industry (Boscariol *et al*., 2010). From the data collected from China's high-tech industry statistics yearbook, since 1995, the number of patent applications in China's pharmaceutical industry increased rapidly, as shown in fig. 1.

The total number of patent applications for Manufacture of Chemical Medicine (MCE) has been significantly higher than that of Traditional Chinese Herbal Medicine (TCM) and Manufacture of Biological Medicine (MBM) after 2009. The average annual growth rate of patent applications for Manufacture of Biological Medicine is as high as 57.48%, which is significantly higher than 31.95% of TCM and 30.93% of MCM.

Since 1996, the new product values of China's pharmaceutical industry have increased significantly, of which the scale of new chemical products value is far greater than the sum of Chinese Herbal Medicine and Biological Medicine. As shown in fig. 2.

The new product values of China's chemical medicine, Chinese proprietary medicine and biological medicine were 6.8 billions, 1.37 billions and 0.12 billions in 1996, respectively increased to 233.49 billions, 101.99 billions and 42.32 billions in 2014. The average annual growth rate of MBM industry reached to 106.78%, which was much higher than 30.92% of Chinese proprietary medicines and 22.58% of chemical medicine.

The United States began to strengthen high-tech export control to China on the grounds of Tiananmen incident in

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1989 (Falvey *et al*., 2004). In recent years, due to concerning China's economic growth and competitiveness improvement, the United States gradually strengthen discriminatory export control for high-tech against China. For example, in 2009, the US Department of Commerce introduced the "Draft of Export Facilitation" to adjust and simplify the export control procedures to 164 countries and regions, but China is not in the adjustment list. In 2011, the US Department of Commerce introduced the "Strategic Trade License Exception", and implemented trade facilitation measures to 44 countries and regions, which exclude China once again. As high-tech chemical and biomedical technology may be used for research and development of chemical and biological weapons, so the United States implemented strict export control on such sensitive and dual-use items. See table 1.

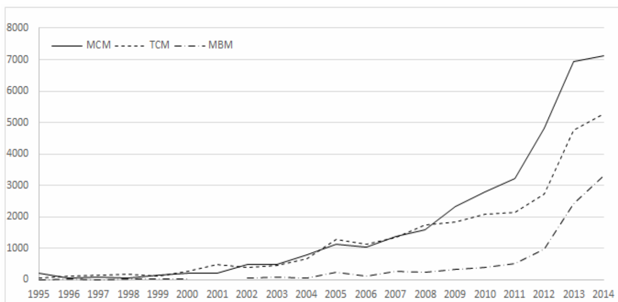

Fig. 1: Growth Trend of Patent Application Number of China's Pharmaceutical Industry

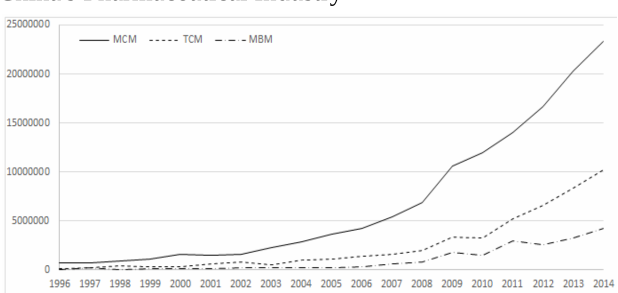

Fig. 2: Growth Trend of New Product Output Value of China's pharmaceutical industry

As we can see from table 1, both the US Military List and Commercial Control List are involved in biological and chemical pharmacy and technology control. Some of items are strictly prohibited export to China, or require a complex license application, or obtain rigorous end-user certification and end-use review. At present, China's demand for importing pharmaceuticals and related equipment is increasing due to the increasing population, aging trends and rapid growth in economy. The strict export controls resulted in China's imports of high-tech biological and chemical pharmaceutical products from the United States is very limited.

This paper selected two categories of drugs for which China has a large demand, vaccines for human medicine, HS code 300220, and Penicillins or Derivatives, HS code 300410, to explore the extent of US exports control to China, as shown in fig. 3.

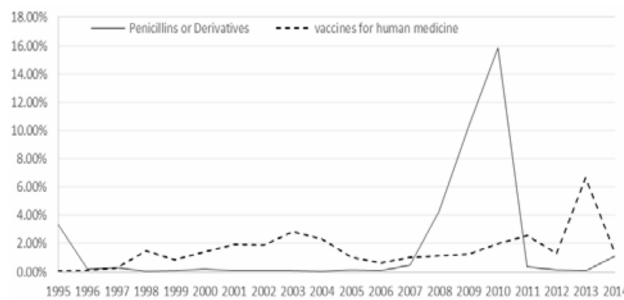

Fig. 3: Ratio of U.S. Export for China to Export for World

China has a strong demand for high-tech pharmaceutical products, and the United States has a unique competitive advantage in the field of medical technology, in accordance with the trade division of labor and comparative advantage theory, China should import a large number of chemical and biological drugs from the United States. But because of the US export control policy, the human-use vaccine exported to China only accounted to 1.6% of U.S. total exports, which is far from to serve the vaccine needs of China as the biggest population country in the world.

US high-tech export control hindered the export of advanced medical equipment and products to China, which not only cannot meet the demand for advanced medicine arising from China's economic development and population growth, but also there is a potential impact on technological innovation of China's high-tech pharmaceutical industry (Madsen, 2007). The export control increase the trade cost and harm the productivity (Melitz, 2003). Imports have productivity selection and technology spillover effects. Imports involved advanced foreign technologies can improve local firms' technologies (Acharya, 2008). U.S. export control policy is one of the most important tools available to enforce the national security and foreign policy interests and its allies (Rajeswari, 2014). The U.S. export restriction to China do creates extra expenditure of industries in China on research and development (Chunmei, 2016).

The foregoing can be found that China's pharmaceutical industry under the strict control of the United States have still been significantly improved in technological innovation and market competitiveness. Therefore, does the strict export control of the United States have an impact on technological innovation of China's high-tech pharmaceutical manufacturing industry? If the impact is significant, what is its internal path of action?

Therefore, this paper made a thorough analysis on effects of U.S. export control in high-new technology on innovation of pharmaceutical industry in China, with concrete information are shown as below.

MATERIALS AND METHODS

General information

This paper is divided the pharmaceutical industry into three categories: Manufacture of Chemical Medicine (MCM), Production of Finished Traditional Chinese Herbal Medicine(TCM) and Manufacture of Biological Medicine(MBM) according to the standard of high-tech industry in China, collected technical innovation data of the three selected sectors from 1995 through 2014 according to the China High Technology Industry Statistical Yearbook, and collected pharmaceutical import and export trade data from the United Nations commodity trade database. Then significance test is made as follows:

The first step, this paper was test whether the US export control policy has significantly affected the technology spillover to China's high-tech pharmaceutical industry. I use the expenditure of high-tech adoption (HTA) from foreign country to measure technology spillovers.

The second step, we tested whether technology spillover is the driving force for innovation of China's pharmaceutical industry.

This paper constructed two panel regression models based on the above research contents. The models included following variables, such as the total output value (TPV), the expenditure of purchase domestic technology (PDT), the domestic research and development (DRD), the time trend variable and the annual dummy variable. We made panel regression analysis after verifying the stability of each variable.

Export control intensity

This paper referred the trade freedom index (Baldwin, 2003) and amended it to measure the intensity of export control, $\mathrm{ECI} = \sqrt{\frac{m_{CA}m_{AC}}{x_{AW}x_{CW}}}$, m_{CA} is China's imports from the United States, m_{AC} is US imports from China , x_{CW} is China 's total exports to the world , x_{AW} is US total exports to the world。The smaller the ECI, the more severe export control.

Technical innovation ability

The quality and quantity of technological innovation are often difficult to measure directly (Hill, 1979), but can be measured indirectly as follows: First, from the perspective of input, including the R & D, the number of scientific and technical personnel, and the amount of technology introduction; Second, from the perspective of output, such as the number of patent applications and authorizations; Third, from a comprehensive perspective, the representative of the indicators is total factor productivity (TFP). This paper chooses the number of patent applications to measure the innovation ability of pharmaceutical industry in China. In order to meet the requirements of the panel model for the same order of regression, this paper considered the level value and logarithm value of the number of patent applications.

STATISTICAL ANALYSIS

The panel data model mainly includes three types: mixed regression model, fixed effect model and random effect model. In the specific data processing, the Houseman test is usually used to determine which model is suitable for the data processing. However, the random model requires that the number of coefficients to be estimated is less than the number of the data section, because the section of this study is only three, and the estimated coefficient is much more than 3, so it is not suitable to choose random effect model.

This paper used eviews7 software for regression analysis. We choose approaches of Levin, Breitung T-stat, Pesaran and Shin, ADF and PP of Fisher Chi-square to test the stationarity of selected variables. According to the level test, first order difference test and Logarithm first order difference test, it is found that the variables HTA, ECI, PAT and PDT are first order stationary, the variables TPV and DRD are logarithmic first-order stationary.

RESULTS

There was a statistical significance between export control (ECI) and technology spillover (HTA and LOG (HTA) (P>0.05), as shown in table 2.There was no statistical significance between the technology spillover (HTA) and innovation (LOG(PAT) (P>0.05), as shown in table 3. In order to satisfy the conditions of the same order regression of each variable, the results obtained after the model correction are shown in Table 4. The impact of technology spillovers on technological innovation is still insignificant.

DISCUSSION

According to the above static analyses based on pooled least squares, the US export control policy is a major constraint on technology spillovers to China. If the technology spillover is the key factor that affects the technological innovation of China's pharmaceutical industry, it means that the export control of the United States have a direct impact on the technological innovation of China's pharmaceutical industry (Alavi *et al*., 2016). But contrary to the above inference, statistical analysis proved that foreign technology spillover did not play a key role on the innovation of pharmaceutical industry in China, and the technological innovation of China's pharmaceutical industry relies more on internal or domestic technology spillovers, rather than foreign technology spillovers.

Table 1: Control List of US Biology and Chemistry Pharmacy

Citation	Category or ECCN	Contents
United States Munitions List	Category XIV-Toxicological Agents	Chemical agents, such as Nerve agents, Amiton, Vesicant agents, Incapacitating agents
		Biological agents
		Antibodies, polynucleoides, biopolymers or biocatalysts
		Medical countermeasures, to include pre- and post-treatments, vaccines, antidotes and medical diagnostics
Commerce Control List	2B352	Biological containment facilities, isolators, manufacturing equipment & facilities and safety cabinets
	1A984	Chemical agents
	1E351	Chemical disposal technology
	1E350	Chemical production facility technology
	2B350	Chemical manufacturing equipment and facilities

Table 2: Effects of export control on technology spillover

Dependent Variable	Significance Test	Independent Variable ECI	Controlled Variable LOG (TPV?)
LOG (HTA?)	t	2.408	0.146
	P	0.002	0.000
HTA?	t	-2.573	8.593
	P	0.014	0.000

Table 3: Effects of technology spillover on innovation

Dependent variable	Significance Test	Independent Variable LOG (HTA?)	Controlled Variable LOG (PDT?)	Controlled Variable LOG (DRD?)
LOG (PAT?)	t	0.765	3.538	-0.252
	P	0.449	0.001	0.803

Table 4: Effects of technology spillover on innovation (Modified Model)

Dependent variable	Significance Test	Independent Variable HTA?	Controlled Variable PDT?	Controlled Variable LOG (DRD?)
PAT?	t	-1.179	7.907	1.072
	P	0.246	0.000	0.291

Since the United States export control only has indirect effect on innovation capability of Chinese pharmaceutical industry, and cannot stop effectively the technology innovation of China, then adjustment of export control policy to China is not only conducive to the expansion of U.S. exports to China, but also to meet China's growing demand for importing high-tech medicine. As Wendt (2011) pointed out that Commercial demands lead technology development, not military need, so the USA should cut the Gordian Knot of export controls and unshackle its' competitiveness while providing sufficient protection of some key defense technologies.

CONCLUSION

From above analysis, we can draw a conclusion that China's technological innovation in the pharmaceutical industry has not significantly benefited from technology spillovers from the United States due to export control. US export controls, while preventing foreign spillovers to China, have spurred domestic technological spillovers in China's pharmaceutical manufacturing industry, relevant support evidence is that the impact of expenditure of high technology adoption from abroad on innovation of China's pharmaceutical manufacturing industry is not significant, but the purchase of domestic technology is essential to the pharmaceutical innovation. China's State Council clearly pointed out that one of the innovative directions of the pharmaceutical industry during "thirteen five period" is to strengthen the structural reform of supply, the focus is to meet people's need for urgent medicine, strengthen research and innovation in the field of the original research medicine, the first drug, Chinese medicine, new formulations, and high-end medical equipment, speed up the industrialization of pharmacy cured some frequent disease, such as cancer, diabetes, cardiovascular and cerebrovascular diseases and some rare disease. Regardless of whether the United States to adjust the export control to Chinese medicine, the technological innovation of China's pharmaceutical industry has always insisted on independent innovation and continuous innovation.

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