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External Dependence and Independent Innovation in Technology Catching up-Analysis on the Development of Advanced Manufacturing Technology in Japan

Jianhong He, Shan Luo and Xiaoyu Yang *

School of Economics and Management, Chongqing University of Posts and Telecommunications, Chongqing 400065, China

Abstract

Advanced manufacturing technology is the key field of technological advantage competition in the world's major industrial countries. Japan is a good example, who have successfully completed the transformation and upgrading of manufacturing industry, and finally established the path of technology catch-up and global value chain climbing through balancing independent innovation and external dependence in the past half century. In this paper, the author reviews the construction of the panel data set of scientific papers and invention patents in Japan's advanced manufacturing technology field from 1996 to 2018, discusses and verifies the impact of independent innovation and external dependence on technology development, and analyzes the internal path to explore its technology transition. The results show that, Firstly, in Japan, a certain level of external technology dependence and independent innovation significantly promote the innovation performance of advanced manufacturing industry; Secondly, the life cycle of advanced manufacturing technology significantly promotes the positive impact of independent innovation on innovation performance; Thirdly, the life cycle of advanced manufacturing technology negatively moderates the relationship between external dependence and innovation performance.

Keywords

Advanced manufacturing technology; Independent innovation; Technology introduction; Degree of dependence on foreign technology; Technology life cycle.

1. Introduction

Advanced manufacturing technology is characterized by high investment, fast iteration, centralized supply of core components, and high dependence on ecosystem (Luigi et al., 2018; Wang et al., 2020) , which undertook the important mission of reconstructing the world manufacturing pattern and global value chain (Mourtzis et al., 2019). As result, it has developed rapidly around the world and gradually formed a development pattern with the United States, Japan and Germany taking the lead, followed by China, India and South Korea (Farooq et al., 2017). From the perspective of sub fields of advanced manufacturing technology, Japan is at the world's leading level in such sub fields as high-speed processing, forced forming of materials and CNC machine tools (Barrientos et al., 2016). This kind of leadership comes from several rounds of strategic choices in its development history. For example, Japan also experienced the transformation and upgrading of advanced manufacturing industry at the end of the 20th century and the beginning of the 21st century. Developing countries, such as China and India , are faced with the situation of transformation and upgrading of manufacturing industry and the catching up state, which are very similar to that of Japan at that time (Basu et al., 2018; Li，2018； Julian et al., 2018; Bao Long et al., 2017;). Therefore, Japan's layout in the field of advanced manufacturing technology, key technology breakthroughs, and the choice of independent and cooperative innovation strategies may have profound implications for the current development of advanced technology in developing countries.

From the perspective of technology catch-up theory, the effectiveness of independent innovation and technology introduction as the main means of technology catch-up in late-developing economies has always been a hot topic for researchers to discuss (Nepelski and De Prato, 2018). Some researchers believe that by means of technology introduction, catch-up costs such as time and human resources can be saved and the gap between technology pursuers and technology leaders can be quickly narrowed. A series of classic discussions were addressed with the theories of "latecomer advantage" and "window of opportunity" (Xsya and Bta, 2019; Keun Lee and Franco Malerba, 2016; Zaclicever and pellandra, 2018; Kumar，2004）. Other researchers believe that from the perspective of technology catch-up performance, the effect of technology introduction has a short-term effect, and the blind emphasis on technology introduction will even form path dependence and inhibit the innovation ability of the economy. Therefore, they believe that independent innovation is the main driving force for late-developing economies from catching up to surpassing, and the economies that are at the edge of the trade value network and at the low end of the global value chain can climb up through independent innovation. (Guo and Zhang, 2019; Paula et al., 2018).

From the perspective of technology field heterogeneity, some researchers believe that independent innovation and technology introduction should not be completely separated (Yu et al., 2020; Miao et al., 2018), and their interaction is more effective for the agglomeration of advanced manufacturing innovation resources and the emergence of innovative technology. They believe that catch-up economies communicate with the outside world through technology introduction and keep up with the change of cutting-edge technology in the world (Ungan, 2015). Whereas independent innovation makes them "free of technology", while internal and external factors such as technology life cycle, technology coupling degree and economic environment will only affect the weight of the two (Li and Wu, 2010; Tseng et al, 2011; Taylor et al., 2012; Utterback, 1994). In the process of Japan's advanced manufacturing technology catch-up and development, there are not only strategies to introduce and absorb technology, but also independent innovation efforts based on the strategy of "building the country through science and technology" and industrial policy incentive. Together, they promote the continuous innovation of advanced manufacturing technology and become the source of leading edge (Lynn, 1998; Machado et al., 2020; Min et al., 2019; Regele et al., 2018; Aoki and Staeblein, 2017). However, issues such as the heterogeneity of Japan's role efficiency in different technological stages and fields of advanced manufacturing technology development (vertically), as well as the independence and interaction of Japan's role in policy guidance and technological innovation strategy adjustment and transformation (horizontally) are not clear, which need to be further studied. R&D

Based on data on technology import investment, R&D investment and original publications of the field of advanced manufacturing technology in Japan from 1996 to 2018, this paper defines the development cycle of Japan and its leading advantage in different technology fields, and discusses the efficiency difference between independent innovation and external dependence. After that, the authors analyze the spatial and temporal constraints of foreign import and independent innovation strategies in the catch-up scenario of advanced manufacturing technology development. The authors expect that the research results will provide strategic suggestions for developing countries on the path selection of current advanced manufacturing technology innovation. Based on this, this paper tries to explore the differences in the efficiency of independent innovation and external dependence. Then, this paper analyzes the constraints of space and time in the development of advanced manufacturing technology in the context of catching up, so that providing strategic suggestions for developing countries about the path selection of advanced manufacturing technology innovation.

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2. Brief History of Advanced Manufacturing Technology in Japan

2.1. From Learning Imitation to Leading by Oneself

The innovation of advanced manufacturing technology in Japan has experienced a process of pursuing from imitation to independence. The development of Japan's advanced manufacturing technology began with the introduction of technology from Britain and the United States. In the later stage, independent innovation plays a more important role. With these two strategies, Japan has completed the industrial transformation and upgrading in the past two decades. At present, Japan ranks at the forefront of the world in advanced manufacturing fields such as CNC machine tools and robots, and has successfully transformed itself from a later-rising country to a leading country. In order to have a clearer understanding of Japan's choice of foreign technology dependence and independent innovation at different technological stages, the author briefly reviewed the history of Japanese manufacturing industry since World War II and summarized the key events (Table 1).

Table 1 Key events in the development of advanced manufacturing technology in Modern Japan

Time	Event
1940	Set up the Department of industrial technology to reform the organization of science and technology
1950	The law of the people's Republic of China on investment and development has determined "technology introduction" as the main development strategy
1956~1961	The R&D investment of enterprises increases by 30% ~ 40% every year
1970	The manufacturing industry is changing to the energy-saving and efficiency type, and the technology is further upgraded; The proportion of new technology introduction is reduced
1980	Issue "white paper on science and technology", emphasizing the establishment of science and technology
1982	The output of lathe ranks first in the world and becomes the main supplier of robot in the world
Late 1980s	Formulate the outline of science and technology policy, and make use of independent technology to become the leading country in advanced manufacturing fields such as semiconductor
1990s	The emergence of the bubble economy accelerated the transformation and upgrading of the manufacturing industry.
Early 21st century	Advocate the cooperation among industry, University and enterprise

Through a brief review of the key historical events in modern Japanese manufacturing industry, we can draw the following conclusions. Firstly, after the Second World War, Japan revitalized its economy mainly through the recovery of manufacturing industry. In the early stage, the main manifestation was the introduction of advanced manufacturing technology, then imitation and innovation. At the time, Japan's outdated technology criticized for copying and then limited the quality of its products. Secondly, since the 1960s, the consciousness of independent innovation began to wake up in Japan's advanced manufacturing industry, further developed strategy of "building the country through science and technology" (Watanabe C et al., 2003). Japan began to develop education to cultivate talents with independent innovation, and the government

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began to introduce relevant policies to encourage independent innovation and improve the quality of innovation. Thirdly, the crisis brought by Japan's bubble economy accelerated the transformation and upgrading of Japan's manufacturing industry. At the end of the 20th century, Japan's manufacturing industry began to shift to technology-intensive industries, and low-end manufacture reduced or even abandoned. The nineties of the 20th century was the heyday of Japanese manufacturing industry. With the comprehensive arrival of the information age, the manufacturing industry all over the world has entered a new era, in which advanced manufacturing technology has become the mainstay of the development of the manufacturing industry. Japan has entered a new round of manufacturing technology innovation based on independent innovation (Lee et al., 2016; Naoyuki et al., 2016).

2.2. Cycle Alternation

From the manufacturing history of modern Japan, its advanced manufacturing technology presents the characteristics of dynamic change. As shown in Figure 1, in the 1940s-1950s, Japan's manufacturing industry was mainly concentrated in machinery, shipbuilding and other heavy industries. From 1970s to 1980s, Japan's electrical machinery and semiconductor industry became the main force of manufacturing industry. In the 21st century, Japan's manufacturing industry has successfully transformed and upgraded, and has become a world leader in advanced manufacturing fields such as CNC machine tools and robots.

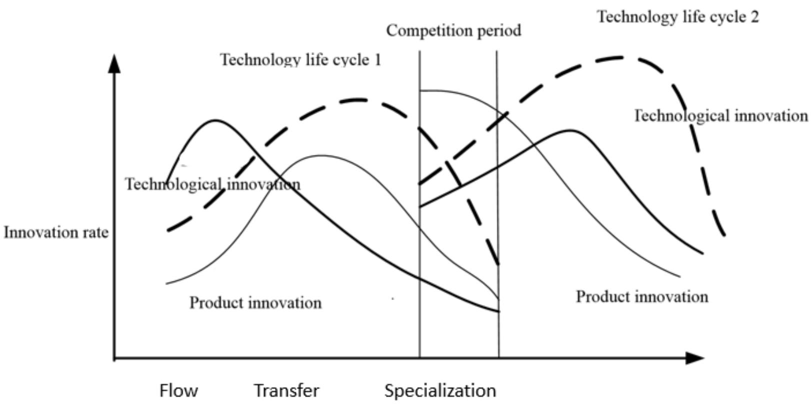

Figure 1 A-U model of modern advanced manufacturing technology in Japan

Based on the perspective of A-U model, the development of modern advanced manufacturing technology in Japan presents cyclical characteristics. In the first stage, the advanced manufacturing technology innovation of Japanese manufacturing industry had the form of anti-a-u model from 1940 to 1990. In the 1940s the advanced manufacturing technology innovation started with the introduction of technology. At the beginning of this stage, the process innovation rate is higher than the product innovation rate. That is to say, in this stage, the innovation focused on the re-innovates the introduced process technology, which further leads to the innovation of products and technologies. The second stage is from 1990 to 2000. This is a competition period of A-U model in Japanese manufacturing industry. The upgrading of labor factors promoted the start of technological and product innovation. The competition period is also called the fracture period, which has the characteristics of breaking through the original technological track and leaping technological innovation. In the third stage, Japan became a technology frontier country at the end of the 20th century. A large number of technologies introduced a new embryonic stage in the technology life cycle, and the independent innovation in this stage was the main driving force for the further upgrading and innovation of advanced manufacturing technology. Therefore, the new round of advanced manufacturing innovation in Japan started, which is based on independent innovation, as shown in the standard A-U model in Figure 1.

Generally speaking, from 1940s to 1980s, Japan's advanced manufacturing technology completed a cycle of transformation, and its leading position in the world was established by the interaction of independent technological innovation and external dependence. From 1990s, new production factors promoted a new round of transformation and upgrading of advanced manufacturing industry. At present, Japan's advanced manufacturing technology is in the stage of development (germination, growth, innovation and innovation) and the technology diversity is also more abundant. Based on this, the application of foreign introduction and independent innovation strategies in the multi cycle evolution of advanced manufacturing technology will be explored in this paper. The article will compare the role of the different innovation strategy transformation in promoting the technological level, and then discuss the strategy selection of advanced manufacturing technology innovation in the context of technology catching up or leading.

3. Theoretical Basis and Research Hypothesis

3.1. Independent Innovation and Innovation Performance of Advanced Manufacturing Technology in the Context of Technology Catching up

From the perspective of technological catch-up, independent innovation promotes technological progress and upgrading in both cutting-edge countries and catch-up countries. For the technology catch-up countries, the knowledge and technology of the frontier countries are absorbed mainly through collaborative innovation and transnational research and development. With the narrowing of the technological gap with the cutting-edge countries of advanced manufacturing technology, the technological benefits brought by cooperative research and development are becoming less, while the role of independent innovation is becoming more significant (Zhengyi et al., 2017). For technology-leading countries, in the critical period of industrial structure transformation, the advantages brought by labor force are already small, while independent innovation can bring new impetus for economic development (Sun Y et al., 2020).

R&D time is also a catalyst for independent innovation. In the short run, independent innovation is not conducive to the upgrading of industrial structure, but in the long run, it has a positive impact on the upgrading of industrial structure, especially on high-tech industries, while the mechanism of technology introduction is just the opposite (Liping et al., 2019). Therefore, independent innovation is the only way for the long-term development of manufacturing industry. There were research results showing that although Japan's GDP has a positive correlation with foreign direct investment in the short term, there are problems of weak structural absorption and technology spillover. The long-term plan for development is to improve the independent innovation ecosystem (Nakamuura and Zhang, 2018). In the short run, technology introduction promotes employment, but the spillover effect of employment is not obvious. In the long run, technology introduction has a destructive effect on employment. Although independent innovation destroys employment in the short run, it constructs an ecosystem that promotes employment in the long run, and the spillover effect of employment is more obvious (Manlio et al., 2019). Based on the above research, this paper puts forward the following hypotheses

H1: There is a positive correlation between independent innovation and innovation performance in the context of technology catch-up, that is, the improvement of the degree of independent innovation directly promotes the performance of technological innovation.

3.2. External Dependence and Innovation Performance of Advanced Manufacturing Technology in the Context of Technology Catching up

The concrete manifestations of foreign dependence are the introduction of technology, the cooperation in trade and the study of knowledge and theory. There are many forms of the introduction of technology including the construction of an international R&D network, the use of excellent technical talents and technical knowledge of the host country, and the set up of technological progress in the home country (Righetto et al., 2019). Cooperation in trade refers to importing products from other countries to meet the needs of domestic technology shortages (Wang, 2018). The study of knowledge and theory is to introduce foreign cutting-edge knowledge and provide strong knowledge base guarantee for technology research and development through local absorption (Stornelli et al., 2018). In the context of technology catch-up, the external dependence of technology in advanced technology innovation mainly manifested in the exchange and cooperation with other countries in advanced manufacturing technology, such as importing machinery and equipment from other countries, introducing and absorbing talents from other countries, etc. External technology dependence is a kind of inward technological innovation and a way to realize independent innovation. Take China as an example. In the 1990s, China's core equipment was backward, key talents were scarce, and the development of advanced manufacturing technology was very slow. However, since China's accession to the WTO, the technology has become more and more dependent on foreign countries, and the technology experience and talents of developed countries have been actively introduced, which has achieved a leap in economy and technology in a relatively short period. Therefore, a country can gradually realize independent innovation by introducing and absorbing foreign advanced technology through foreign direct investment. It can be seen that the rational use of other countries' human and material resources is a shortcut to technological upgrading, and the introduction of technology to the host country can promote the upgrading of home country technology (Wang and Hu, 2020). Based on this, this paper puts forward the following hypotheses

H2: In the context of technology catch-up, there is a positive correlation between external dependence of advanced manufacturing technology and innovation performance, that is, foreign technology introduction and cooperation promote technological innovation performance.

3.3. Regulatory Role of Technology Life Cycle

The life cycle of advanced manufacturing technology can be divided into germination period, growth period, maturity period and decline period. The development of advanced manufacturing technology can be divided into development period and decline period according to the difference of technology maturity and innovation strategy. In the initial stage of the development period of advanced manufacturing technology, the independent innovation ability of the innovation subject is insufficient, and the probability of innovation success is very small. Through technical guidance, the innovation subject cooperates with other countries, absorbs foreign advanced technical knowledge, cultivates advanced manufacturing technical talents matching with national conditions, and introduces foreign advanced equipment disassembly and analysis. It accumulates the necessary knowledge base for the final independent innovation (Bergerson et al., 2020). In the middle and later stages of development, with the continuous accumulation of knowledge and technology and the increase of R&D investment, the ability of independent innovation of innovation subject has been greatly improved. At this time, the government tends to guide resources into the field of advanced manufacturing through industrial policies, promote technological innovation and technological replacement, catalyze the technology application ecology, and improve the output efficiency of technological innovation. In the middle and late development stage, the innovation space of independent innovation has been greatly developed, The trial and error cost of independent innovation is reduced, and the promotion effect of independent innovation on innovation performance is greatly improved. Therefore, the following hypotheses are put forward

H3: Technology life cycle positively regulates the relationship between independent innovation and technological innovation of advanced manufacturing technology.

In the development period of advanced manufacturing technology, due to the lack of awareness of new technology, more countries will seek foreign cooperation as the main method to develop advanced manufacturing technology. When the technology accumulates to a certain extent, excessive dependence on foreign technology will inhibit the improvement of domestic innovation ability, and will produce the inertia of technological innovation. This will negatively affect the further upgrading of the industry, leading to the countries become a follower in the field of advanced manufacturing. Taking China as an example, technology introduction is the main driving force of China's advanced manufacturing technology in the pre catch-up stage. Foreign direct investment and the establishment of international R&D network are the main ways to introduce technology. Depending on the technology spillover effect of the two, on the surface, the technology gap between China and developed countries is gradually narrowing, but China still has no say in the field of advanced manufacturing (Liao et al., 2020). As a technology late-comer, foreign cooperation and R&D of technology is a shortcut to quickly move closer to the technology frontier countries. Relying on the establishment of international R&D network and the introduction of foreign advanced talents, absorbing their technical advantages can greatly improve technical capability in developing countries, increase the possibility of secondary innovation on the basis of the introduction of foreign technology R&D (Linton, 2017). However, the innovation performance of late developing economies had not been substantially improved, which reflected in the large number and poor quality of patents. In the development period, appropriate external technology dependence can improve the efficiency of technological innovation, but excessive dependence on foreign technology will fall into the trap of introduction absorption re introduction. In this contest, the innovation ability of the home country will not be improved, and then the key technology fields will be strangled. One of the characteristics of advanced manufacturing technology is the rapid change of technology, so the recession period lasts for a very short time. Disruptive technologies often begin to sprout in the recession period, and the new technology track arises at the historic moment. Dependence will make the home country become the follower of technology and subject to the technology leader. Based on the above conclusions, this paper puts forward the following hypotheses

H4: Technology life cycle negatively regulates the relationship between foreign cooperation and technological innovation of advanced manufacturing technology.

Based on the above analysis and research hypotheses, the theoretical framework of this study can be obtained, as shown in Figure 2

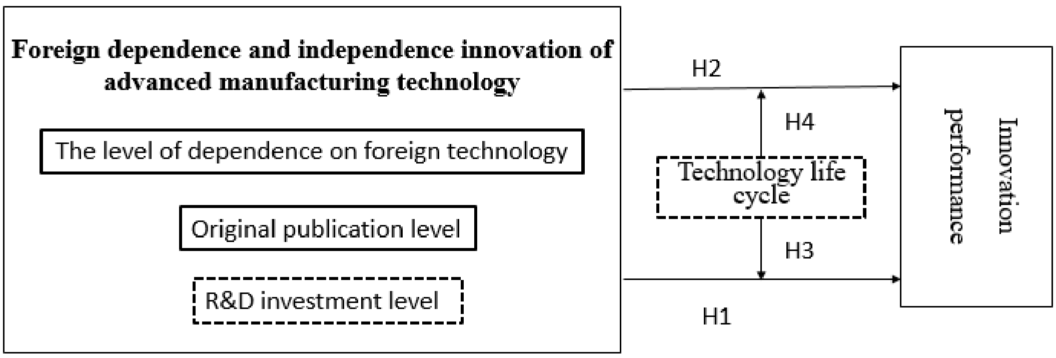

Figure 2 the theoretical framework of this paper

4. Research Design

4.1. Model Design

There is no unified measurement method for foreign technology dependence at the moment. The original method to calculate the degree of dependence on foreign technology is to measure the degree of dependence on foreign technology by the ratio of technology introduction funds to R&D investment. Some research data show that it is the most reliable and closest to the actual situation to use the two factors of foreign investment funds and technology introduction funds as the measurement indicators of foreign technology (Chan-Yuan, 2013). The research object of this paper is Japan's advanced manufacturing technology, and the main form of its external dependence is the introduction of technology, including the introduction of equipment and talents. Based on the actual situation of Japan and the availability of data, foreign investment in Japan is not the main reason for the development of technology in recent years（Hitomi, 2004; Raja et al.,2017）

$$dependence = \frac{F}{F+R\&D} \tag{1}$$

F is the technology introduction fund. The research has divided the advanced manufacturing technology into 11 sub areas, and this research will be based on the 11 technologies. Therefore, on the basis of formula (1), it subdivides the dependence of each advanced manufacturing technology on external technology in this paper. Considering that the import of high-end equipment is one of the specific forms of advanced manufacturing technology introduction in Japan. Therefore, the formula for calculating the dependence of foreign technology is formula (2), $a_i$among which the equipment value of advanced manufacturing technology of class I and the value of the three types of technical equipment imported by Japan are the sum of the value of the low, medium and high-level technical equipment imported by Japan. The maximum and minimum of the dependence on foreign technology are 1 and 0. When it is equal to 1, the domestic R&D investment is 0, which indicates that the development of technology is entirely dependent on the introduction of technology; When it is equal to 0, there is no introduction of technology.

$$dependence_i = \frac{F}{F*\frac{a_i}{A}+R\&D_i} * \frac{a_i}{A} \tag{2}$$

Model (3) is the basic model of this paper. Where I is the i-th technology, t is the time trend, kl is the level of original knowledge, this paper considers the average number of citations or number of original publications , ε_{it}as random interference term.

$$y_{it} = \alpha_0 + \alpha_1 dependence_{it} + \alpha_2 kl_{it} + \varepsilon_{it} \tag{3}$$

On the basis of the basic model, control variables and regulatory variables is introduced. Among them, the adjustment variable is the technology life cycle. In this paper, we divide it into two stages: the development stage and the recession stage. We use the 0,1 variable representation.

$$y_{it} = \alpha_0 + D(\alpha_1 dependence_{it} + \alpha_2 kl_{it}) + \alpha_3 per_{it} + \gamma D + \varepsilon_{it} \tag{4}$$

4.2. Variables

4.2.1. Dependent Variable

Therefore, the definition and collection of data in this paper are based on 11 advanced manufacturing technologies. Advanced manufacturing technology (AMT) is a relatively large technology system. There are significant differences in development process and evolution track among different technology fields in the system, which can be further divided into multiple technology sub fields。

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The innovation performance of advanced manufacturing industry is mainly represented by the transformation of innovation achievements. Innovation performance is generally measured by the sales revenue of new products or patents. But patents can better represent the novelty of products. The research of a single industry shows that most of the existing researches use the amount of patent authorization and patent applications to measure innovation performance (Challis et al., 2005; Aldier et al., 2018). Based on the availability of data, this paper selects the number of patent applications of 11 advanced manufacturing technologies in Japan as a measure of innovation performance.

4.2.2. Independent Variable

Independent innovation is an independent innovation activity within the country. The input of R&D personnel and funds is the most commonly used indicator to measure independent innovation. However, some research results show that absorptive capacity is necessary for technological innovation in technology frontier countries, and the output of knowledge has a great impact on the absorptive capacity of Technology (Petti et al., 2019; Leydesdorff et al., 2019; Grimaldi and cricelli, 2020). So knowledge output is the basis of technological innovation. Therefore, the results of high-level original knowledge is used in this paper, that is, the level of Japanese original publications (the average number of citations or numbers of high-quality original publications) is used as an indicator of independent innovation (Dziallas and Blind, 2018). That is, the average cited rate and quantity of original publications.

Foreign technological dependence. The degree of dependence of existing research on external technology is mainly measured by the degree of dependence on external technology. He said to what extent a country's technological progress depends on the introduction of external technology. The foreign technology dependence in this paper refers to the complementary activities between Japan and other countries, that is, Japan's introduction of equipment in advanced manufacturing technology. So we choose the degree of dependence on foreign technology to express the degree of foreign cooperation. Therefore, the explanatory variable is the dependence of Japan's advanced manufacturing technology on foreign technology. The main calculation data of foreign technology dependence include Japan's technology introduction funds and R & D investment, and the value of imported machinery and equipment.

4.2.3. Control Variable

R&D activities will be affected by many factors, among which R&D funds and R&D personnel will have a direct impact on the innovation performance of enterprises (Martin, 2016; Chen and Sun, 2000; Paulo et al., 2019). However, at the national level, the population base and economic size of different countries vary greatly. Based on the existing literature, the ratio of R&D funds to researchers is used to express the level of R&D investment (per), and takes it as a control variable.

4.2.4. Moderator Variables

Technology life cycle of advanced manufacturing technology. From the development history of Japan's advanced manufacturing industry, the impact of external technology dependence and independent innovation on technological innovation performance is not the same. With the change of technological maturity, Japan is also adjusting the proportion of independent innovation and external dependence to ensure technological output, and the emphasis of national development strategy is different under different technological states. Therefore, the maturity of technology will affect the impact of independent innovation and external dependence on innovation performance. Therefore, this paper introduces the technology life cycle of advanced manufacturing technology as an adjusting variable. According to the maturity of advanced manufacturing technology and the change of innovation efficiency, this paper divides advanced manufacturing technology into development period and decline period.

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The definition and measurement of the above variables are shown in Table 2.

Table 2 variable definition and measurement

variable	Variable name	Variable description	Express
Explained variable	Innovation performance of advanced manufacturing technology	Patent applications for advanced manufacturing technology	y
Explanatory variable	Independent innovation	The level of publications of advanced manufacturing technology, the average number of citations or the number of publications	cited
			quantity
	External dependence	Foreign technology dependence of advanced manufacturing technology	dependence
control variable	R&D investment	Ratio of R&D funds to R&D personnel in advanced manufacturing technology field	per
Regulatory variables	Technology life cycle	The development and decline period of advanced manufacturing technology life cycle	D

4.3. Data Resources

There are five data sources in this article:

(1) World patent database (WIPO). The patent data of this paper comes from WIPO database. Specifically, on the WIPO search page, the index is set as the applied technology patent, the type is set as the statistical total, the time is 1996-2018, and the organization is Japan. Then, the patents related to Japan's advanced manufacturing technology are selected according to the technology classification, and classified according to 11 sub fields, and finally the data reflecting Japan's advanced manufacturing technology innovation performance is formed.

(2) "SCIMAGOJR" website. The source of the publication data of this paper is " SCIMAGOJR " database. First, select the subject area and its corresponding subject directory in turn, and then select East Asian countries. Finally, the number of publications and the average number of citations in the 23 years from 1996 to 2018 are counted in the list, and then the fields and advanced manufacturing technology are matched, which are divided into 11 sub fields of advanced manufacturing technology.

(3) Official website of the World Economic Cooperation Organization (OECD). The data of R&D investment and R&D personnel in this article comes from the Century OECD database. Enter the database on the homepage of the official website, click the database access button to enter the database, select the data classified by subject, then download the R&D expenditure table and R&D personnel table classified by industry, and finally classified and summarized into 11 sub-fields, thereby obtaining the data of each field R.

(4) United Nations Trade Development Database (UNCTAD). The data of equipment introduction comes from this data. Enter "Statistic" on the homepage, then enter the data center, select the trade structure sub-option under the catalog of international merchandise trade, and then select the import and export trade table by commodity classification. Finally, select Japan in the economy column of the table, the import and export option is import, and the import value of each high-end commodity is counted in turn, classified and summarized into 11 sub-

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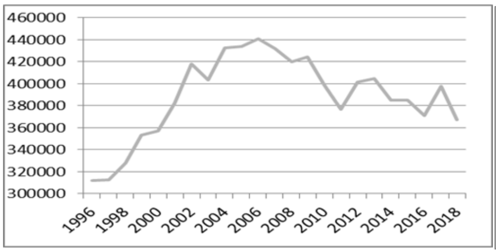
fields of advanced manufacturing technology, so that each field's share of foreign technology dependence is obtained proportion.

(5) Relevant Japanese database. Among them, the funds for technology introduction come from the statistical bureau of Japan. Enter the data page on the home page, and then enter the R & D funds statistical survey page to find the technology introduction funds from 1996 to 2018.

5. Analysis

5.1. Descriptive Statistics

Firstly, the sample population is preliminarily estimated, and the overall trend chart of innovation performance and external dependence is drawn by using the sample data. Figure 3 and Figure 4 show the total number of patents and the percentage of overall external dependence of 11 advanced manufacturing technologies in Japan from 1996 to 2018, respectively. The number of patent applications and external technology dependence reached the peak in 2007. The difference is that the number of patent applications began to decline since then, while the external technology dependence began to rebound in 2010. The specific and more detailed relationship between the two needs to be further verified.



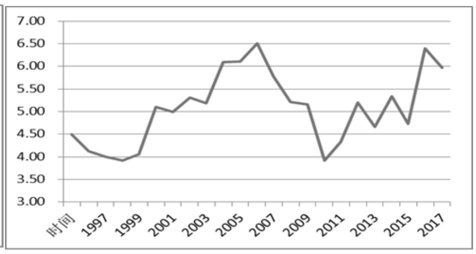


Figure 3 Patent trend chart Figure 4 Trend of dependence on foreign technology

The external technology dependence of each sub field is shown in Table 3. The sample size of each sub domain is 23, and the standard deviation is less than the mean value, indicating that there is no extreme value. On average, the external dependence of Japanese industrial robot technology is the highest, and the external technology dependence of enterprise resource planning and high-speed processing technology is the lowest. The possible reason is that industrial robots are emerging technologies, and Japan is more inclined to introduce technology to countries with better technology to achieve rapid development of technology. However, the enterprise resource planning and high-speed processing technology are mature technologies in Japan. Japan has formed its own technology development system, and its development is no longer dependent on technology introduction. The standard deviation of the degree of dependence of industrial robot on foreign technology is the biggest. It indicates that Japan is constantly adjusting the technology innovation strategy in the process of developing the technology, trying to find the most suitable external technology dependence for the development of technology. This also shows that industrial robot is one of the key areas of advanced manufacturing technology development in Japan. There are significant differences in the degree of dependence between sub domains, which indicates that Japan has different development strategies for different advanced manufacturing technologies.

Table 3 Descriptive statistics of external technology dependence of each sub field

technical field	sample size	mean value	standard deviation	minimum value	Maximum
Computer aided design technology	23	0.157	0.052	0.093	0.318

Forced forming technology of materials	23	0.063	0.025	0.029	0.114
Ultra precision machining technology	23	0.047	0.021	0.031	0.107
High speed machining technology	23	0.012	0.003	0.006	0.018
Additive manufacturing technology	23	0.065	0.029	0.025	0.096
Micro nano manufacturing technology	23	0.091	0.021	0.053	0.119
Remanufacturing technology	23	0.076	0.015	0.044	0.097
Bio-inspired Manufacturing Technology	23	0.016	0.010	0.007	0.044
numerical control machine	23	0.155	0.080	0.031	0.241
Industrial robot	23	0.283	0.116	0.088	0.446
Enterprise resource planning	23	0.012	0.008	0.003	0.024

The trend of average citation times of papers in each sub field from 1996 to 2018 is shown in Figure 5. Since the beginning of the 21st century, the average number of citations of papers in various sub fields has shown a downward trend, and the degree of independent innovation has declined, which may be related to the social and economic environment Japan is facing in the new era. The trend is consistent with the patent chart in Figure 3, and the relationship between them needs to be further explored.

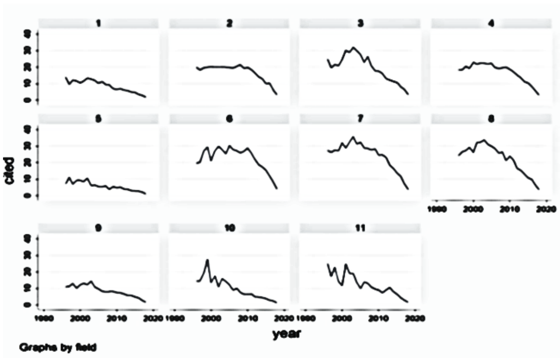


Figure 5 1996-2018 trend of average citation times of sub field papers

The descriptive statistical results of each variable are shown in Table 4. The number of samples of patent application, external technology dependence and publication average cited times is 253. Due to the lack of data, the sample size of R&D funds is 229. The standard deviation in the table is less than the mean value, indicating that there is no extreme value. The maximum value of foreign technology dependence is 44.6%, the minimum value is 1.33%, and the average is 8.94%. Firstly, it shows that the foreign dependence of advanced manufacturing technology in Japan is not high, so the introduction of technology to other innovation subjects is not the main path of technological innovation. In this paper, we also carry out the Vif test, and the Vif values of each variable are less than 10. The results show that there is no multiple collinearity between the variables.

ISSN: 2664-9640

Table 4 descriptive statistics of variables

variable		sample size	mean value	standard deviation	minimum value	Maximum	vif
Explained variable	y	253	35329.22	20479	6604	86697	
Explanatory variable	cited	253	15.29	8.81	1.06	35.84	1.20
	dependence (%)	253	8.94	8.82	1.33	44.6	1.16
	quantity	253	9256.85	7491.83	314	29450	1.08
control variable	per	229	26.11	11.95	7.34	65.97	1.01
Regulatory variables	D	253					

The data of this paper is based on the annual data of 23 years from 1996 to 2018. The cross-section is 11 sub fields of advanced manufacturing technology in Japan. Therefore, the panel data of this paper is long panel data. In view of the three major problems of heteroscedasticity, intra group autocorrelation and inter group contemporaneous correlation in long panel data, this paper makes a test. The test results are shown in Table 5. The three tests show that the p value of the test is zero, so the original hypothesis is rejected, that is, there are problems of heteroscedasticity, intra group autocorrelation and inter group correlation at the same time, so it is necessary to correct these three problems at the same time. Therefore, this paper uses comprehensive FGLS to estimate.

Table 5 Correlation and heteroscedasticity test

test	Heteroscedasticity test	In group autocorrelation test	Synchronous correlation between groups
p	Prob>chi2=0	Prob>F=0	Pr = 0

5.2. Regression Results

Table 6 shows the correlation coefficient matrix. It can be found from the table that innovation performance has a significant positive correlation with external technology dependence, the average number of citations of original publications and the number of original publications at 95% - 99% confidence level. The results preliminarily confirm the derivation of this paper, but the specific correlation needs to be further discussed under the control of other influencing factors, This paper will test the impact of foreign cooperation and independent innovation of advanced manufacturing technology on innovation performance after controlling relevant factors.

Table 6correlation coefficient

	y	dependence	cited	quantity	*per*
y	1				
dependence	0.2223***	1			
cited	0.1321**	-0.3497***	1		
quantity	0.2458***	0.0885	-0.0571	1	
per	0.3452***	-0.2079**	0.1615**	-0.0988	1

Note: *p<0.05，**p<0.01

Based on the data set of this paper, comprehensive FGLS method will be used for regression analysis， and the time effect of long panel will be controlled by adding time trend term. The average cited times and quantity of publications can represent the degree of knowledge innovation of a country to a certain extent. This paper will test these two indicators respectively. The stepwise regression method was used to add control variables. The results are shown in Table 7. Among them, model 1 and model 3 represent the regression models with the average number of citations and the number of original publications as independent innovation indicators respectively. The regression results show that the average number of citations of publications is significant at the level of 99%, while the number of original publications is not significant. The R-square of the former model is also larger than that of the latter model, and the time effect is more significant, indicating that the average number of citations of original publications has a more significant impact on innovation performance, and the number of publications can not represent the quality. Model 2 shows that there is no significant correlation between the number of publications and the innovation performance of advanced manufacturing technology, so the average citation times of publications is used as an index to measure independent innovation. Model 3-4 shows the regression of adding control variables step by step, and the results show that when the R&D investment level and technology life cycle remain unchanged, the external technology dependence and the average number of citations of original publications are significant at the 99% confidence level. In other words, external dependence and independent innovation have a positive impact on technology innovation performance. Both hypothesis 1 and hypothesis 2 hold. Combined with the actual situation of Japan, Japan's advanced manufacturing technology is currently in the forefront of the world, and its technology spillover from external dependence is very small, with high marginal cost. Its low degree of dependence on foreign technology indicates that the degree of dependence on foreign technology is not high, and the main means of development is independent innovation. So independent innovation is the main means to promote the development of advanced manufacturing technology.

Table 7 Determination of variables

variable	model1	model2	model3	model4	model5
dependence	205.2** 81.18	180.2** 76.63	259.5*** 84.44	213.9*** 79.15	262.7*** 85.14
cited	208.2*** 74.42		218.9*** 77.17	272.8*** 75.11	284.0*** 76.48
quantity		0.0669 0.2			
per			46.00** 20.82		48.88** 21.24
D				2819.2*** 1073.1	1830.3* 1076.9
t	320.3***	168	251.8**	387.4***	324.6***
R-sq	0.885	0.787	0.913	0.916	0.932

Notes：*p<0.05，**p<0.01

At different stages of technological life, the innovation performance of technological innovation has different degrees of reflection on its influencing factors. The research has divided the technology life cycle of advanced manufacturing technology into germination, growth, maturity and decline through logistic model. In different stages, the main innovation path and required innovation resources will change (Bergerson et al.,2020). Based on this, the life cycle of advanced manufacturing technology is regarded as the control variable, and the sprouting, growth and maturity are grouped into the development period of technology. The regression was performed with 0, 1 virtual variables. The regression results are shown in Table 8. The interaction terms of technology life cycle and external technology dependence are significant in models 6 and 8, and the coefficient is negative. It indicates that the life cycle of advanced manufacturing technology in Japan negatively regulates the relationship between its external technology dependence and the number of advanced manufacturing technology patents. Hypothesis 3 shows that in the development period of advanced manufacturing technology, the greater the dependence on the outside, the worse the innovation performance. The possible reason is that Japan, as one of the world's leading producers of advanced manufacturing technology, only obtains some basic human and material resources in its foreign cooperation, and the innovation of key core technology mainly relies on independent innovation. The average number of citations of original publications is still significant in the interaction items of the technology life cycle, and the coefficient is positive. That is, as technology matures, if the degree of independent innovation is higher, the better the innovation performance will be. Hypothesis 4 is true.

Table 8 Regulatory role of technology life cycle

	model(6)	model(7)	model（8）
dependence	357.6*** 86.86	244.7*** 84.62	335.9*** 90.18
cited	338.4*** 75	121 128.2	248.9* 129.4
dependence*D	-277.2*** 80.68		-243.8* 86.69
cited*D		202.2* 119.2	97.78* 119.3
per	32.87 21.03	44.11** 20.8	32.28 21.01
D	251 1179.8	-4831.7** 2261.6	-1437.7 2488.1
t	408.8***	351.0***	408.2***
cons	22317.3***	1473.6***	21850.4***
R-sq	0.941	0.934	0.945

Notes：*p<0.05，**p<0.01

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5.3. Robustness Check

Further, in order to test the reliability of the model, this paper uses the method of re-classification to test the robustness. The 11 kinds of advanced manufacturing technology are classified according to processing technology, manufacturing technology and design technology. Secondly, in order to eliminate the problem of endogeneity between data, this paper will use the way of lagging one period and two periods to test the robustness. The two tests are shown in model 5 and 6. j=1,2

$$\sum y_{it} = \alpha_0 + D(\alpha_1 \sum \frac{F}{F*\frac{a_i}{A}+R\&D_i} * \frac{a_i}{A}) + \alpha_2 \sum cited_{it} + \alpha_3 per_{it} + \gamma D + \varepsilon_{it} \quad (5)$$

$$y_{it} = \alpha_0 + D(\alpha_1 dependence_{it-j} + \alpha_2 kl_{it}) + \alpha_3 per_{it-j} + \gamma D + \varepsilon_{it-j} \quad (6)$$

Firstly, the robustness of the model is tested in the following ways. From the perspective of the relationship between technology and products, 11 kinds of advanced manufacturing technologies are classified into three categories: manufacturing technology, processing technology and design technology. Correlation test and heteroscedasticity test is conducted for the two methods respectively, and then comprehensive FGLS regression was conducted. The regression results are shown in model 10 in Table 9. The regression results show that technology dependence is significant at 99% level, and the average number of citations of high-quality publications is significant at 99% level, which indicates that both external dependence and independent innovation have a positive impact on innovation performance. It negatively regulates the relationship between external technology dependence and advanced manufacturing technology patents. It is consistent with the empirical results. Classification and reorganization also shows that in the development period, independent innovation can promote the innovation performance of advanced manufacturing technology, while external dependence can inhibit the innovation performance. The results are consistent with the model used in this paper.

Table 9 Robustness test table

	model9	model10	model11	model12
dependence	2801.4*** 707.6	2344.7*** 717.4	3365.0*** -780.2	2285.0*** 706
cited	2675.2*** 34104	2832.7*** 333.7	2552.1*** -330.6	2132.5*** 474.7
per	474.6 293.5	664.9** 296.9	501.5 -325.7	634.4** 296.0
D	-6776.9*** 2007.0	-16156.6** 6485.2	18892.0*** -6959.6	-28873.3*** 9357.8
dependence*D		1405.7 918.5		-1771.1* 917.8
D* cited			-1339.0** -529.7	718.7** 334.4

t	2883.8*** 322.4	3108.5*** 328.9	2470.7*** -300.9	2992.3*** 313.0
N	69	69	69	69
R-sq	0.989	0.990	0.987	0.991

Notes：*p<0.05，**p<0.01

Secondly, the explained variables are lagged for one and two periods respectively to test the relationship between the explained variables and the explained variables, as shown in table 10. The first issue of this paper refers to one variable *year*, one year is short-term, whereas two years is long-term. Model 13 represents one lag period without adjusting variables, model 14 represents one lag period with technology life cycle as adjusting variables, model 15 represents two lag periods without adjusting variables, and model 16 represents two lag periods with adjusting variables. From the model, 13 kinds of technology dependence have a significant positive impact on the innovation performance of advanced manufacturing technology, while the average number of citations of publications has no significant correlation with the number of patent applications. In model 14, the product of external technology dependence and technology life cycle is negative, which indicates that technology life cycle negatively regulates external technology dependence and innovation performance of advanced manufacturing technology. The product of the average citation times of publications and the technology life cycle is significant. In model 15, the external technology dependence is not significant, and the average number of citations of publications is still significant. In model 16, the significance of interaction items is the same as that in model 14. From model 13 and model 14, it can be concluded that in the development period of advanced manufacturing technology, independent innovation is the main means to promote innovation performance. From model 13 and model 15, it can be concluded that in the long run, independent innovation is the fundamental to improve the advanced manufacturing technology, while the dependence on foreign technology only plays a short-term role and does not have long-term effect;

Table 10 Lag test table

	one period lagged		two phases lagged	
	model 13	model 14	model 15	model 16
dependence	97.66 (79.85)	212.2*** (80.15)	293.3 (84.07)	274.2*** (80.07)
cited	432.3*** (85.66)	386.7*** (122.5)	290.0*** (181.4)	159.7** (147.7)
dependence*D		-323.0*** -73.34		-203.9* -86.22
cited*D		49.78* -113		183.2* -134
per	16.78 (22.86)	2.451 (21.09)	49.99** (23.25)	38.78 (24.22)

ISSN: 2664-9640

D	-2944.4** (1213.1)	-220.3 (2334.9)	-3549.6*** (1150.4)	-4044.4* (2453.0)
t	394.6*** (113.5)	428.6*** (106.8)	401.4*** (91.11)	441.5*** (88.97)
cons	25542.6*** (2429.5)	24193.7***(2744.0)	25028.3*** (2290.6)	25733.3*** (2813.1)
R-sq	0.933	0.937	0.941	0.947

Notes：*p<0.05，**p<0.01

6. Conclusion

6.1. Main Conclusions

Based on the statistical data of 11 sub-fields of advanced manufacturing technology from 1996 to 2018 in the relevant Japanese database, combined with the regulatory role of the technology life cycle of advanced manufacturing technology, the impact of Japan's advanced manufacturing technology's external dependence and independent innovation on innovation performance in the context of technology catch-up are studied this paper. The results are as follows.

Firstly, in Japan, the level of foreign technology dependence of advanced manufacturing technology has a positive impact on its innovation performance, that is, the country's adoption of technology introduction strategy can improve the innovation performance of advanced manufacturing technology. Furthermore, Japan's average dependence on foreign technology of advanced manufacturing technology is 8.94%. Compared with developing countries such as China, this figure shows that Japan's degree of technology import is very low, and technology import is not the main way for Japan to develop advanced manufacturing technology.

Secondly, in Japan, the quality of high-level publications in the field of advanced manufacturing foreign technology has a positive impact on its innovation performance, that is, national independent innovation can significantly promote innovation performance. The average number of citations of its high-level publications is 15.29, which is in the world's top level, indicating that the degree of independent innovation is very high. External technology dependence and the average number of citations of publications have a positive impact on innovation performance. That is to say, both independent innovation and external dependence have a positive impact on the innovation performance of advanced manufacturing technology. However, Japan's low dependence on foreign technology indicates that it has little dependence on other countries in terms of advanced manufacturing technology. And the technology life cycle has a negative impact on the relationship between external dependence and innovation performance of advanced manufacturing technology. So at this stage as the development period of advanced manufacturing technology, independent innovation should be focused to develop advanced manufacturing technology.

Thirdly, through the analysis of the results of the explained variables lagging one and two periods, the promotion effect of independent innovation on advanced manufacturing technology is more lasting from the long-term effect,, and the dependence on foreign technology will have a negative effect on the innovation effect of advanced manufacturing technology in the long run.

6.2. Management Inspiration

Combined with the research conclusion, the following enlightenment is drawn:

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Firstly, based on the current world pattern and the actual situation of developing countries' key technologies, independent innovation should become the main means for developing countries to develop advanced manufacturing technologies at this stage. Independent innovation does not mean that it blocks the door of the countries, while maintaining a certain degree of external technology dependence in independent innovation will more effectively promote innovation performance. The real independent innovation is to realize "technology freedom" in the key core technology, and firmly grasp the advanced manufacturing technology related to the national lifeline in their own hands. It is worth noting that in the development period of advanced manufacturing technology, increasing independent innovation can more effectively promote the improvement of innovation performance. Therefore, we can further explore the characteristics of its technology life cycle under conditions of developing countries and make rational use of it to improve innovation performance more efficiently.

Secondly, foreign cooperation optimizes the innovation quantity and efficiency of domestic enterprises to a certain extent, but excessive dependence on foreign cooperation will make the quality of innovation worse. On the output of innovation performance, it is shown as "emphasizing quantity and neglecting quality". Therefore, developing countries should re-examine the impact of foreign cooperation on innovation performance, and select high-quality economies for foreign cooperation. At the same time, independent innovation and R&D investment should be addressed to achieve substantial technological innovation. Both methods should be used together to accelerate the high-quality development of developing countries' technological innovation.

Thirdly, build a complete "technology ecosystem" in developing countries is essential. At present, developing countries' technology is mostly concentrated in the middle and low end of the manufacturing chain“ The "high-end, refined and sophisticated" equipment mainly depends on imports. Once the importing countries block developing countries' trade, developing countries' advanced manufacturing industry is likely to stagnate, which will lead to economic problems. Therefore, it is essential to build a bottom-up "technology ecosystem" belonging to developing countries.

Fourthly, the accumulation and transformation of original knowledge should attract more attention. Original knowledge refers to the knowledge that is produced independently and belongs to the creator completely in the situation that does not depend on others. It is a reflection of the independent innovation ability of a country. The independent innovation of this paper is based on the knowledge transformation results. The results show that the quality of publications has a positive effect on innovation performance. Knowledge is the source of innovation, the essence of technology introduction is to introduce foreign knowledge. One of the important roles of globalization is to realize the interaction and sharing of global knowledge. Technology progress can only be realized by constantly updating knowledge. Furthermore, knowledge transformation ability can reflect innovation ability more than knowledge accumulation, and knowledge digestion and absorption is the effective way to improve innovation performance. In recent years, the patent in developing countries has exploded, but the patent of appearance design and utility model accounts for the vast majority, and the real invention patents are relatively small. Developing countries should actively adjust the policies and incline the relevant incentive and preferential policies to the application research.

6.3. Contribution

The theoretical contributions of this paper are as follows. First, each sub field of advanced manufacturing technology has its own characteristics. The independent innovation degree, foreign cooperation level and innovation performance of each sub field are different from other sub fields. The conclusion of this study is only applicable to a sub field of technology. Therefore, through the research of 11 sub fields of advanced manufacturing technology, the paper finds that the foreign cooperation and independent innovation in each sub field are promoting innovation performance, enriching the relevant research theories of advanced manufacturing technology. Second, the research focuses on the development of advanced manufacturing technology in the developed countries, and absorbs the experience of its technological progress, which provides a theoretical basis for developing countries to cross the barriers of advanced manufacturing technology. At present, the focus of developing countries' development of advanced manufacturing industry should be on the independent innovation of technology. Only by building the domestic innovation ecosystem through independent innovation and mastering the key core technology can we realize "technology freedom". Third, through the regulation of technology life cycle and the lag of innovation performance, the core position of independent innovation is becoming more and more prominent. 11 advanced manufacturing technologies are in the development period at present. Developing countries should grasp this feature and firmly develop independent innovation.

Disclosure Statement

No potential conflict of interest was reported by the authors.

References

[1] Aoki K, Staeblein T. 2017. "Monozukuri capability and dynamic product variety: An analysis of the design-manufacturing interface at Japanese and German automakers." Technovation 70(71),33-45.

[2] Barrientos S , Knorringa P , Evers B , et al. 2016. "Shifting regional dynamics of global value chains: Implications for economic and social upgrading in African horticulture." Environment & Planning A- ECONOMY AND SPACE 48(7), 1266-1283.

[3] Basu, A.. Foland, G., Holdridge, D., Shelton, D. 2018. "China's rising leadership in science and technology: quantitative and qualitative indicators." Scientometrics 117(1), 249-269.

[4] Bergerson J, Cucurachi S,Seager T P. 2020. "Bringing a life cycle perspective to emerging technology development." Journal of Industrial Ecology 24(1),6-10.

[5] Challis D., Samson D., Lawson B. 2005. "Impact of technological, organizational and human resource investments on employee and manufacturing performance: Australian and New Zealand evidence." International Journal of Production Research 43(1),81-107.

[6] Chan-Yuan Wong. 2013. "On a path to creative destruction: science, technology and science-based technological trajectories of Japan and South Korea." Scientometrics 96(1), 323-336.

[7] Chen X , Sun C . 2000. "Technology transfer to China: alliances of Chinese enterprises with western technology exporters." Technovation 20(7),353-362.

[8] Dziallas M, Blind K. 2019. "Innovation indicators throughout the innovation process: An extensive literature analysis." Technovation 80(3/4),3-29.

[9] Farooq S , Cheng Y , Matthiesen R V , et al. 2017. "Management of automation and advanced manufacturing technology (AAMT) in the context of global manufacturing." International Journal of Production Research 55(5),1455-1458.

[10] Grimaldi, C. 2020. "Indexes of patent value: a systematic literature review and classification." Knowledge Management Research & Practice 18(2),214-233.

[11] Guo L , Zhang M Y , Dodgson M , et al. 2019. "Seizing windows of opportunity by using technology-building and market-seeking strategies in tandem: Huawei's sustained catch-up in the global market." Asia Pacific Journal of Management 36(3),849-879.

[12] Hitomi, K.2004. "Efficiency analysis of Japan's industry and manufacturing." Technovation 24(9), 741-748.

[13] Julian M. Müller,Kai-Ingo Voigt. 2018. "Sustainable Industrial Value Creation in SMEs: A Comparison between Industry 4.0 and Made in China 2025." International Journal of Precision Engineering and Manufacturing-Green Technology 5(5),659-670.

[14] Kumar K V . 2004. “Import-led technological capability: a comparative analysis of Indian and Indonesian manufacturing firms.” Technovation 24(12),979-993.

[15] Lee A ,Mudambi R , Cano-Kollmann M . 2016. “An analysis of Japan's connectivity to the global innovation system.” Multinational Business Review 24(4), 399-423.

[16] Lee K , Franco Malerba. 2016. “Catch-up cycles and changes in industrial leadership: Windows of opportunity and responses of firms and countries in the evolution of sectoral systems.” Research Policy 46(2),338-351.

[17] Leydesdorff L, Caroline S. Wagner,I.,Jordan A. Comins,F. 2019. “Synergy in the knowledge base of U.S. innovation systems at national, state, and regional levels: The contributions of high-tech manufacturing and knowledge-intensive services.” Journal of the Association for Information Science and Technology 70(10),1108-1123.

[18] Li D , Capone G , Malerba F . 2019. “The long march to catch-up: A history-friendly model of China's mobile communications industry.” Research Policy 48(3), 649-664.

[19] Li X , Wu G . 2010. “In-house R&D, technology purchase and innovation: empirical evidences from Chinese hi-tech industries, 1995-2004.” International Journal of Technology Management 51(2/3/4),217-238.

[20] Li, Ling. 2018. “China's manufacturing locus in 2025: With a comparison of "Made-in-China 2025" and "Industry 4.0".” Technological Forecasting and Social Change 135(10),66-74.

[21] Liao H, Yang L, Ma H , et al. 2020. “Technology import, secondary innovation, and industrial structure optimization: A potential innovation strategy for China.” Pacific Economic Review 25(2),145-160.

[22] Linton, D. 2017. “Emerging Technology Supply Chains.” Technovation 62-63(4-5),1-3.

[23] Luigi Aldieri,Vania Sena,Concetto Paolo Vinci. 2018. “Domestic R&D spillovers and absorptive capacity: Some evidence for US, Europe and Japan.” International Journal of Production Economics 198(1), 38-49.

[24] Lynn L H . 1998. “The commercialization of the transistor radio in Japan: the functioning of an innovation community.” Engineering Management IEEE Transactions 45(3),220-229.

[25] Machado C G ,Winroth M P , Silva D . 2020. “Sustainable manufacturing in Industry 4.0: an emerging research agenda.” International Journal of Production Research 58(5),1462-1484.

[26] Manlio Del Giudice, Alexeis Garcia-Perez,Veronica Scuotto.2019. “Are social enterprises technological innovative? A quantitative analysis on social entrepreneurs in emerging countries.” Technological Forecasting and Social Change 148(C),119704-119704.

[27] Martin R. 2016. “R&D policy instruments - a critical review of what we do and don't know.” Industry and Innovation 23(2),157-176.

[28] Miao Y , Song J , Lee K , et al. 2018. “Technological catch-up by east Asian firms: Trends, issues, and future research agenda.” Asia Pacific Journal of Management 35(3),639-669.

[29] Min Y K , Lee S G , Aoshima Y . 2019. “A comparative study on industrial spillover effects among Korea, China, the USA, Germany and Japan.” Industrial Management & Data Systems 119(3),454-472.

[30] Mourtzis D ,Fotia S , Boli N , et al. 2019. “Modelling and quantification of industry 4.0 manufacturing complexity based on information theory: a robotics case study.” International Journal of Production Research 57(22),1-14.

[31] Nakamura M , Zhang A . 2018. “Foreign direct investment with host country market structures, with empirical application to Japan.” Journal of the Japanese and International Economies 49(1),43-53.

[32] Naoyuki, Yoshino, Farhad, et al. 2016. “Causes and Remedies of the Japan's Long-lasting Recession: Lessons for China.” China & World Economy 24(2),23-47.

[33] Nepelski, D., De Prato, G.2018. “The structure and evolution of ICT global innovation network.” Industry and Innovation 25(10),940-965.

[34] Paula Anzola-Román, Cristina Bayona-Sáez, Teresa García-Marco. 2018. "Organizational innovation, internal R&D and externally sourced innovation practices: Effects on technological innovation outcomes." Journal of Business Research 91(10),233-247.

[35] Paulo N., Figueiredo, M C.2019. "Explaining early entry into path-creation technological catch-up in the forestry and pulp industry: Evidence from Brazil." Research Policy 48(7),1694-1713.

[36] Petti C , Tang Y , Margherita A . 2019. "Technological innovation vs technological backwardness patterns in latecomer firms: An absorptive capacity perspective." Journal of Engineering & Technology Management 51(51),10-20.

[37] Raja Roy, Susan K. Cohen.2017. "Stock of downstream complementary assets as a catalyst for product innovation during technological change in the U.S. machine tool industry." Strategic Management Journal 38(6),1253-1267.

[38] Regele, Lindsay, Schakenbach. 2018. "Industrial Manifest Destiny: American Firearms Manufacturing and Antebellum Expansion." Business History Review 92(1),57-83.

[39] Righetto L , Spelta A , Rabosio E , et al. 2019. "Long-term correlations in short, non-stationary time series: an application to international R&D collaborations." Journal of Informetrics 13(2),583-592.

[40] Stornelli Aldo, Ozcan Sercan, Simms Christopher.2021. "Advanced manufacturing technology adoption and innovation: A systematic literature review on barriers, enablers, and innovation types." Research Policy 50(6),1-21.

[41] Taylor M, Taylor A. 2012. "The technology life cycle: Conceptualization and managerial implications." International Journal of Production Economics 140(1),541-553.

[42] Tseng M, Hsieh H, Peng YN. 2011. "Using patent data to analyze trends and the technological strategies of the amorphous silicon thin-film solar cell industry." Technological Forecasting and Social Change 78(2),332-345.

[43] Ungan, C. 2015. Advanced manufacturing technologies: a survey research. International Journal of Advanced Research 5(8),76-91.

[44] Utterback M. 1994. Mastering the Dynamics of Innovation: How Companies can Seize Opportunities in the Face of Technological Change. Boston: Harvard Business School Press,1994.

[45] Wang C., Hu Q . 2020. "Knowledge sharing in supply chain networks: Effects of collaborative innovation activities and capability on innovation performance." Technovation 94-95(S). DOI:10.1016/j.technovation.2017.12.002.

[46] Wang H . 2018. "China's Approach to the Belt and Road Initiative." Journal of International Economic Law 22(1),29-55.

[47] Wang H Y ,Diao L J . 2013. "On Characteristics and Development Trend of Advanced Manufacturing Technology." Advanced Materials Research 2045(03),712-715.

[48] Wang M , Zhang Z , Li K , et al. 2020. "Research on key technologies of fault diagnosis and early warning for high-end equipment based on intelligent manufacturing and Internet of Things." The International Journal of Advanced Manufacturing Technology 107(3),1039-1048.

[49] Watanabe C. Asgari B. Nagamatsu A. 2003. "Virtuous cycle between R&D, functionality development and assimilation capacity for competitive strategy in Japan's high-technology industry." Technovation 23(11), 879-900.

[50] Xsya B , Bta B . 2019. "Shaping selection environments for industrial catch-up and sustainability transitions: A systemic perspective on endogenizing windows of opportunity." Research Policy 48(4),1030-1047.

[51] Yu L , Li H , Wang Z , et al. 2019. "Technology imports and self-innovation in the context of innovation quality." International Journal of Production Economics 214(8),44-52.

[52] Yu Sun,Ling Li,Hui Shi,Dazhi Chong. 2020. "The transformation and upgrade of China's manufacturing industry in Industry 4.0 era." Systems Research and Behavioral Science 37(4),734-740.

[53] Zaclicever D ,Pellandra A . 2018. "Imported inputs, technology spillovers and productivity: firm-level evidence from Uruguay." Review of World Economics 154(4),725-743.

[54] Zhe, Sun. 2015. “Technology innovation and entrepreneurial state: the development of China's high-speed rail industry.” Technology Analysis & Strategic Management 27(6),646-659.

[55] Zhengyi, ZhangJun, JinMin, et al. 2017. “Catch-up in nanotechnology industry in China from the aspect of process-based innovation.” Asian Journal of Technology Innovation 25(1),5-22.