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A Transition of Technological Distance in Japanese Manufacturing Sectors

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Abstract

This study, using improved methodology on the basis of Jaffe's approach, focuses on the analysis of the trends in technological distance in Japanese manufacturing sectors. New approach in this paper could suggest a practical estimating method considering both horizontal and vertical distance of the input (R&D investment) and output (Make matrix) sides. By utilizing improved methodology, this paper examines the empirical evidence on the impacts of technological distance on technology spillover in 13 Japanese manufacturing sectors.

1. Introduction

A dramatic increase in the transboundary flow of people, goods and information has accelerated the growth and spread of global technology spillovers. Recent economic globalization inevitably accelerates transboundary technology spillovers.

In order to stimulate the spillover effects, assimilation capacity (ability to assimilate technology, Bernstein and Nadiri, 1989, Cohen and Levinthal, 1989) and technological distance seem to play a key role. Among these factors, early studies indicate that stagnation of assimilation capacity is the major source reducing spillover effects in the Japanese manufacturing sectors (Watanabe et al., 2001, Hur & Watanabe, 2002). However, their works deal with only assimilation capacity as a critical factor of spillover, and they don't take technological distance into account as a key role in detail. In order to measure effects of technology spillover, the estimation of a technological distance, although the concept of a distance is very hard to define practically, has an important meaning. Because the technological knowledge can be utilized by other sectors whose technologies are close to it. The closer the distance, technology spillover effects can be occurred more quickly and efficiently.

The concept of technological distance was suggested by Griliches (1979) and developed by Jaffe (1986). Griliches used weighting function in which weighting becomes smaller as the distance increases between sectors. He suggested several kinds of way to estimate technological closeness or distance. Among these suggestions, Jaffe's study (1986) is the well-known example of using technological position vectors.

According to Jaffe, cosine angle is measured by calculating inner product between technological position vectors. Thus, technological distance ranges between 0 and 1. As the distance approaches unity, the closer are the research interests. Namely, if an industry is doing R&D on other industry's R&D, technological distance is closer in some sense. However, it has some shortcomings with this method. Fundamently, distance may have two kinds of meaning. One is horizontal distance and the other is vertical distance. Horizontal distance means the similarity of position vectors among sectors. Jaffe's methodology is close to this horizontal distance. On the other hand, vertical distance can be considered as technology gap between sectors. Although the sectors have the same similarity in their R&D pattern (technological position vector), it cannot cover the technology gap, so that they may have different technological distance due to the different technology gap. Therefore, we have to consider horizontal and vertical distance simultaneously when technological distance is estimated.

Since Jaffe's approach to the technological distance uses only an angle determined by technological position vectors, small input of R&D expenditure devoted to a certain area can affect technological distance in terms of adding new component in technological position vector. His approach didn't take the amount of R&D expenditure into account. For instance, small increase in recent investment of electronic and electrical machinery field in every sector makes technological distance shortening and concentrating to the field of electronic and electrical machinery. Thus, on condition that two sectors invest in a same technology, technological distance become close in Jaffe's method, regardless of the different amount of investment of each sector.

On the one hand, technological distance between two sectors may differ in accordance with the difference of technological level (between donor and host). Actually, technological distance is meaningless from a donor's standpoint since technology flows from donor to host. However, technological distance may be a crucial factor to get spillover effects on a host side. Thus, it is necessary to identify proper standpoints of two sectors. That is, an analysis employing both the amounts of R&D investment and technological distance from a host side should be conducted in order to estimate technological distance more practically.

This paper analyzes the transition of technological distance in the Japanese manufacturing sectors from 1970 to 1997 considering the amounts of R&D investment, and takes vertical and horizontal distance into account in terms of improving Jaffe's concept. Moreover, this analysis demonstrates the transition of technological distance in both input and output sides respectively by utilizing dataset of R&D investment and Make matrix.

2. Analytical framework

Japan's manufacturing sector can be classified into 13 types[1] of sector according to Annual Report on National Accounts (Economic and Social Research Institute Cabinet Office, Government of Japan, annual issues). Based on this classification, dataset of R&D investment and input-output table (especially Make matrix) for the Japanese industries were obtained from Report on the Survey of Research and Development (Statistics Bureau Ministry of Public Management, Home Affairs, Posts and

[1] FD: food, TX: textile, PP: pulp & paper, CH: chemicals, OC: oil & coal, CR: ceramics, PM :primary metal, MP: metal product, TM: transport equipment, GM: general machinery, EM: electrical machinery, PI: precision instrument, OM: other manufacturing.

Telecommunications Japan, annual issues) and from Annual Report on National Accounts. Both are public-use data sets. Input-output matrices usually appear in two parts. The first part, called the Use matrix, has products in its rows and industries in its columns. The entries show the use of each product (in the rows) by each industry (in the columns). The second, called the Make matrix, has industries in the rows and products in the columns; the entries show how much of each product was made in each industry. Specifically, Make matrix clearly shows the distribution on output side because it indicates the distribution by industry of the aggregate output of a commodity both principal products and secondary products for industries. Utilizing these data sets, analysis of trends in technological distance are conducted both input and output side respectively.

According to Jaffe, technological distance or closeness between two sectors was measured in the following manner:

$$D_{ij} = \frac{F_i \cdot F_j}{|F_i||F_j|} \tag{1}$$

where $F_i = (\frac{R_{i1}}{R_i}, \frac{R_{i2}}{R_i}, \cdots, \frac{R_{in}}{R_i})$ and

$$F_j = (\frac{R_{j1}}{R_j}, \frac{R_{j2}}{R_j}, \cdots, \frac{R_{jn}}{R_j})$$

are technological position vectors which indicate the profile of R&D expenditure on technological areas n. R_{in}, R_{jn} is the R&D expenditure of the respective industries devoted to R&D activities in area n.

After computing the technological position vectors, an angle ($\cos\theta$) can be calculated by the concept of inner product. This is exactly the same as Jaffe's approach. Assume that the more amounts of R&D investment are made, technological level is higher than it does not. Once the technological position vectors are obtained, then the magnitudes of vectors are determined. Hypothesize that the magnitude of vector i is relatively larger than that of vector j. Thus, i sector can be considered as the donor and j sector as the host. For the next step, let's consider vector projection of j (host) onto i (donor). Namely, the component of j vector in the direction of i vector is equal to $\|j\|\cos\theta$, and then new distance is obtained by dividing the magnitude of i vector from the pure host standpoint. This methodology provides us improved technological distance describing both horizontal (Jaffe's methodology) and vertical distance (technology gap). Mathematically, this explanation can be expressed as follows:

$$D_{ij} = \frac{\|host\| * \cos\theta}{\|donor\|} = \frac{\|j\|\cos\theta}{\|i\|} \tag{2}$$

Fig 1. shows the projection j onto i graphically.

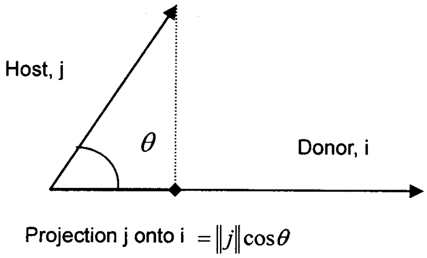

Fig.1. Technological distance from a host standpoint.

On the basis of the above formulation, as the technological distance between two sectors approaches unity, the host has very similar research interests to the donor. It ranges between 0 and 1. Although the cosine angle approaches 1, that is, horizontal distance is similar to each other, if the R&D investment is small, it would affect vertical distance (technology gap). In case the R&D investment is made intensively (small technology gap), distance would be closer despite the different research fields. Thus, two sectors are assumed to be equal if they have the same direction and the same magnitude.

Recently, every sector has been invested in the field of electronical and electrical sector. This phenomenon shortens the distance and it leads to similar research interests automatically by applying only horizontal distance. However, we are not able to say that their research interests are closer each other. Because, in case a sector invest only a small amount mainly for improving their productivity, technological distance remains almost the same. Therefore, considering both horizontal and vertical distance can reduce bias toward estimating technological distance in a proper way.

Based on the improved methodology, this paper focuses on attempting to measure technological distance from a host standpoint taking horizontal and vertical concept into consideration using the dataset of R&D investment and Make matrix of respective sectors. The trends in technological distance between sectors both input and output aspect was plotted utilizing quantification theory type Ⅳ.

3. Empirical analysis

With technological position vectors, it would be possible to know the R&D patterns of Japan's manufacturing sectors. Based on the result of position vectors, it shows the trends in R&D investment to its own respective sectors from 1970 to 1997 (data was omitted due to space limitation). As the portion of expenditure to its own field becomes higher, it implies that the sector is not so active in expanding its fields. On the other hand, as the portion becomes smaller, the sector is considered as the diversified one. Result shows that diversified phenomenon exists at every sector except EM and TM. The percentage of R&D investment in its own field shows different behaviors. EM and TM sectors did a small increment in its own field, and FD, PP and CH shows a small decrement or steady state tendency. The other sectors diversified their fields. In order to see trends in technological distance with respect to each sector and its contribution to spillover effects, mapping both input and output side was plotted by calculating relative technological distance.

In order to describe the relative technological distance, quantification theory type IV was adopted to analyze relative technological distance between sectors that was computed by using only Jaffe's method and improved methodology respectively. First, based on technological position vectors, relative technological distance was plotted by applying only Jaffe's approach. Fig. 2 illustrates the trends in relative distance among manufacturing sectors over the period of 1970 to 1997.

There is no distinctive feature in 1970 and it is rather scattered. By and large in 1980, Japan's manufacturing sector was divided into two groups. First is somewhat traditional group and the other is high technology one like GM, TM and EM etc. From 1990, every sector tends to approach to EM steadily and recently, in 1997, almost all the sectors are concentrated into the area of EM except PP and FD. However, we cannot say that this trend really stands for real trends in technological distance. Since figure only describes horizontal distance, applying only Jaffe's methodology (horizontal distance) may have led to misleading interpretation. Only a small amount of investment towards EM sector can make shorten technological distance regardless of an amount invested to that sector. Therefore, from this point of view, the method of measuring technological distance requires improved one.

With the aim to overcome this shortcoming, improved methodology in analytical framework is applied with the aim of considering horizontal and vertical distance simultaneously. New mapping adopting improved methodology is illustrated in Fig. 3.

Generally, the trend in relative technological distance shows the concentrating tendency to each other from 1980 to 1997 except TM and PP. However, concentrating tendency is not so intensive compared to Fig. 2. Particularly, technological distance becomes closer between EM and the other sectors despite the small increment of R&D investment of EM in its own field. This tendency implies that every sector has been diversified their R&D strategies in order to shorten distance with EM. FD, PP, CH and TM sectors did not show any concentrating tendency in relative technological distance. It coincides with the phenomenon that is explained at the result of position vectors. Broadly speaking, diversification strategies are really made for shortening technological distance, so that shorten technological distance contributes the impact on utilizing technology spillover efficiently.

In order to understand diversified pattern on an R&D side, the trends in technological distance from an output aspect were conducted using the same methodology. Fig. 4 illustrates the trends in technological distance.

Technological distance was very close between sectors in 1971 on an output side. However, it is scattered from 1980 and PP, TX and FD sector have been maintained their own product field. Especially, group including PI,GM, TM,PM,EM,MP,OM is close each other during all the period. However, each position remains nearly still from 1990 on an output side comparing to input side in a broad manner. Especially, comparing figure 3 with 4, outstanding feature between input and output side is the difference between EM and TM. It is closer on output side while its distance is far away each other on R&D side. This discrepancy implies that although R&D strategy becomes diversified over the period of 1970 to 1997 in the Japanese manufacturing sectors, its real trends can be interpreted as a way of improving its productivity or to cope with composite or convergent product emerging recently by shortening technological distance in order to utilize spillover effects instead of expanding product field.

4. Implication

The main objective of this study is to attempt to shed some light on the technological distance trends of both input side and output side among sectors by using dataset of R&D expenditure and Make matrix that covers 13 Japanese manufacturing sectors from 1970 to 1997. In this study, new methodology of estimating technological distance was developed based on Jaffe's approach. The major findings emerged from this study can be summarized as follows:

In line with early studies, the effects of technology spillover have been decreased from the middle of the 1980s in Japan (Watanabe et al., 2001, Hur & Watanabe, 2002). Broadly speaking, technology spillover depends primarily on technological distance and assimilation capacity on a host side. What seems clear is that technological distance of output side remains almost the same in a broad manner despite the shorter trends on R&D. Another key factor to consider is the role of assimilation capacity in maximizing spillover effects on a host side. According to previous research (Watanabe et al., 2001), the trends in assimilation capacity have significantly been decreased from 1981 to 1995. Thus, the diminution of spillover effects in Japanese manufacturing sectors can be attributed to a large range of decline in its assimilation capacity despite the shorter trends in technological distance on an R&D side.

However, if we consider in more detail on an output side, its technological distance becomes scattered pattern from the 1980s and the distance keeps almost the same pattern until 1995 on output side. In case of the distance between EM, TM and the other sectors, while its distance is far away each other on an R&D side, distance is very closer on an output side from 1971. It implies that diversified R&D pattern of concentrating EM may affect mainly improving their own productivity and coping with the recent emergence of composite or convergent product by shortening technological distance instead of expanding the product field.

In summarize, considering the input and output aspect of technological distance, the main reason of the decline of spillover effects in the Japanese 13 manufacturing sectors may be considered as a successive diminution of assimilation capacity rather than technological distance on a host side. In addition, considering the trends in technological distance in the Japanese manufacturing sectors, this study has found it necessary to focus on improving assimilation capacity rather than diversifying R&D strategy to maximize and utilize spillover effects that can get large benefits from other sectors, despite the many factors affect spillover effects in the Japanese manufacturing sectors.

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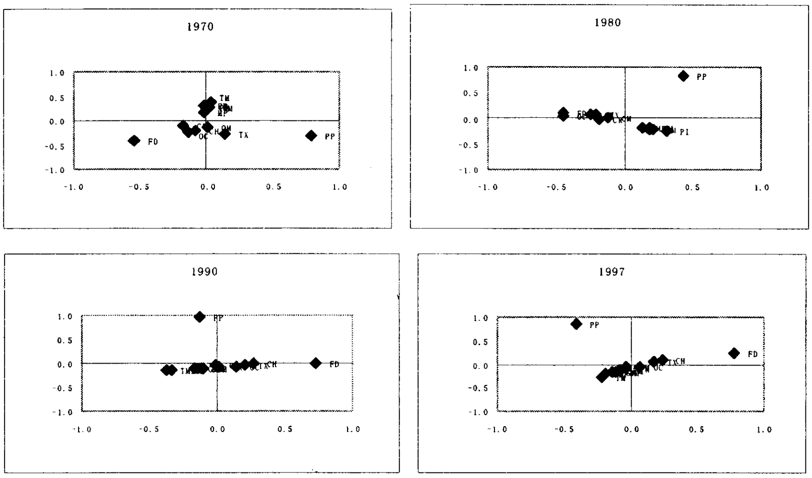

Fig. 2. Trends in technological distance on R&D side (Applying only Jaffe's approach).

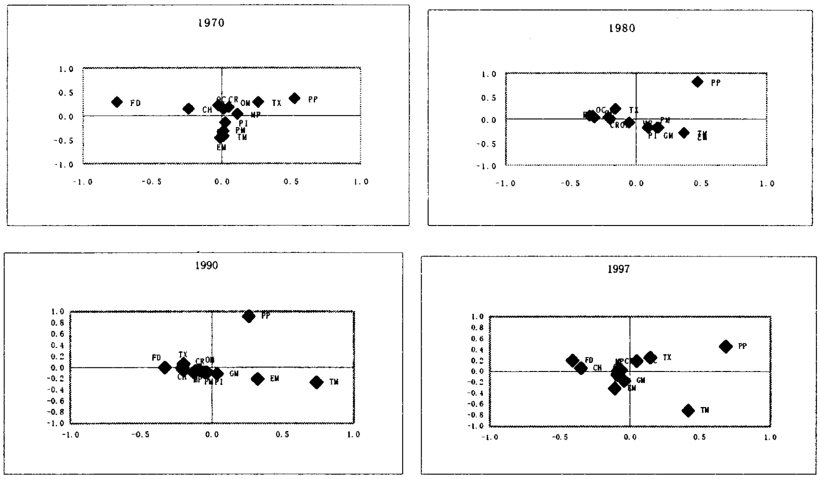

Fig. 3. Trends in technological distance on R&D side (Improved methodology).

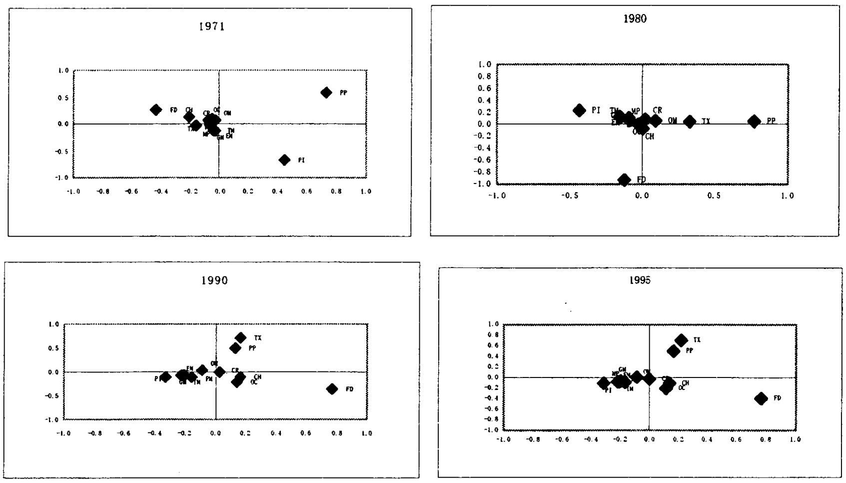

Fig. 4. Trends in technological distance on output side (Improved methodology).