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The R&D Inter-industry Spillover Change in China: on the analysis of 1997 and 2002 IO tables of China

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ABSTRACT

In this paper, backward R&D flow coefficient matrix and forward R&D flow coefficient matrix are defined on the basis of input-output technique. Receiving effect and sending effect are introduced, used to analyze the inter-industry R&D spillovers. By using the 1997 and 2002 input-output tables of China, this paper first computes the backward R&D flow coefficient matrix, the forward R&D flow coefficient matrix, receiving effects and sending effects of 40 industries in China, and analyzes the main flow directions and characteristics of R&D inter-industry spillovers in China. Second, we discuss the inter-industry spillover change, and its tendency of this period by comparing the 2002 result with that of the 1997.

KEY WORDS R&D spillovers, input-output technique, China

1. Introduction

Nowadays, innovation has become more and more important for the socio economic development in China, and seems to be the main source of the technological progress. Innovation mainly comes from the research and development (R&D) activities, which have spillover effects among industries or regions in an economy. That means the R&D activities in one industry can not only benefit itself, but benefit other industries, and a industry gets benefit not only from the effects of the innovative activities created by itself, but also the effects of innovations that are imported from other sectors via intermediary products, investment goods or the use of patents, thus R&D investment in one sector could benefit other sectors and the whole economy.

As an efficient method to analyze the technological relations of all industries in an economy, input-output analysis is a useful tool to model the knowledge flows and the inter-industry R&D spillovers. Many economists analyze R&D spillovers by input-output technology (see Pierre Mohnen, Edward N. Wolff, and other articles in the special issue of *Economic Systems Research*: inter-sectoral R&D spillovers, 1997, No. 1). Axel During and Hermann Schnabl (2000) proposed a method to compute R&D flow matrix and used to compare the inter-industry technology flows in OECD countries: Japan, German, and America. Erik Dietzenbacher & Bart Los (2002) used backward multipliers to indicate at which commodities stimuli should be targeted to enhance R&D and its positive externalities in the economy as a whole.

Innovation and R&D activities are reinforced in China now. Independent innovation is stimulated and encouraged by Chinese government. Thus it is necessary to analyze the R&D inter industry linkage in China. This paper focus on the inter industry R&D spillovers in Chinese economy. As an indicator of the R&D activities, the R&D expenditures of the sectors with respect to the IO table were used. First, the backward and forward R&D-flow-coefficients-matrixes, which are derived from R&D flow matrix, are introduced. Based on the two matrixes, the receiving effect and sending effect are defined and used to analyze the inter-industry R&D spillovers. Then we compute and analyze the R&D spillover change on the base of the 1997 and 2002 input-output tables of China with 40 and 42 sectors respectively.

2.Methodology

Input-output model is as follows:

$$X = (I - A)^{-1} Y \tag{1}$$

where X is the vector of sectoral outputs, and A is the matrix of input coefficients, Y the vector of current final demand. The matrix of input coefficients is obtained by dividing the columns of the intermediate deliveries according to the corresponding gross output levels. That is,

$$a_{ij} = w_{ij} / x_j$$

or

$$A = W < X >^{-1} \tag{2}$$

where W denotes the matrix of domestic intermediate deliveries. <•> is used to indicate the diagonal matrix as obtained from the corresponding vector.

Axuel During（2000）used the idea of subsystems, an interesting component of input-output analysis, to compute the R&D flow matrix. The subsystem model is given as follows.

$$X_{R\&D} = < R\&D >< X >^{-1} (I - A)^{-1} < Y > \tag{3}$$

where *R&D* indicates the vector of sectoral R&D expenditures.

$X_{R\&D}$ is called the R&D-flow matrix or intermediary technology flows. It is an imputation of the R&D-expenditures of the sectors $i(i=1,\cdots, n)$ to the n subsystems. This subsystem approach shows how each sector i 'dedicates' its own R&D-expenditures to the production of its own as well as the other final demand goods j, ($j=1, \cdots, n$). Thus the rows of the R&D flow matrix show to which extent a single row sector i will be a technology deliverer to the production of the other final demand goods. The columns, however, show the contribution of the R&D-efforts of other sectors to the final demand category of that subsystem. This signifies to which extent the producer sector of the corresponding good j is a technology user. Thus, the R&D-flow-matrix $X_{R\&D}$ indicates the imputed inter-industry technology flows (see Axel During & Hermann Schnabl, 2000, or Weber & Schnabl, 1998).

But it is possible that the sum of the final demand of a sector is negative if the inventory decreases too much (Zhang Hongxia, 2003). Thus there will have some difficulty in the analysis of R&D-flow-matrix. Therefore, the R&D-flow-coefficients-matrix is used instead of the R&D-flow-matrix in this paper. The equation of R&D-flow-coefficients-matrix, $C_{R\&D}$ is shown in (4).

$$C_{R\&D} =< R \& D >< X >^{-1} (I - A)^{-1} \tag{4}$$

The jth ($j=1, \cdots,n$) column of $C_{R\&D}$ indicates the contribution of the R&D-efforts of other sectors to yield one unit of the final product of sector j. It means that the jth ($j=1, \cdots,n$) column of $C_{R\&D}$ is the measurement of sector j as an R&D beneficiary from all the other sectors. The sum of the jth column of $C_{R\&D}$ can be used to evaluate the total R&D benefit sector j obtained from other sectors per unit of its final demand. The total beneficiary effect of certain sectors can be computed by

$$MC_{R\&D} = iC_{R\&D} \tag{5}$$

where $i = (1,1,\cdots,1)$. $MC_{R\&D}$ is called receiving effect. It should be noted that $MC_{R\&D}$ is the backward multiplier in fact (see Erik Dietzenbacher & Bart Los, 2002). Therefore, $C_{R\&D}$ is the backward R&D-flow-coefficients-matrix.

In order to show the origin sectors of the R&D spillovers that a certain sector obtained, $C_{R\&D}$ can be standardized by column. That is

$$SC_{R\&D} = C_{R\&D} < MC_{R*D} >^{-1} \tag{6}$$

The jth column of $SC_{R\&D}$ indicates the weights of the sectors in the total $R\&D$ expenditure spillovers that sector j obtained, ($j=1, \cdots, n$).

In order to make the deliverer effects of a certain sector, another kind of R&D-flow-coefficient-matrix is defined by the following equation, called forward R&D-flow-coefficient-matrix.

$$D_{R\&D} =< R \& D >< X >^{-1} (I - A_C)^{-1} \tag{7}$$

where A_C is the output coefficients matrix in input-output technology. A_C is defined by (8).

$$A_C =< X >^{-1} W \tag{8}$$

The certain row of $D_{R\&D}$ can be used to show the *R&D* dedication of a sector *j* ($j=1, \cdots n$)to other sectors and itself as a deliverer when its final demand increases one unit.

The total R&D dedication of certain sectors can be computed as:

$$MD_{R\&D} = D_{R\&D} i^T \tag{9}$$

$MD_{R\&D}$ is defined as sending effect. We can also standardize $D_{R\&D}$ to make the delivering direction more clearly.

Primary diagonals of $C_{R\&D}$ and $D_{R\&D}$ can be replaced with zeros to remove the spillover effect of certain industries to themselves. . That means the R&D spillover of an industry to itself isn't considered in order to analyze the inter-industry spillover more exactly.

3. Database

The database for R&D-flow-coefficients-matrix is 1997 and 2002 input-output tables of China, with 40 and 42 sectors respectively, which are compiled by State Statistical Bureau of China (SSB) and Chinese Academy of Sciences. The database of R&D expenditure is from the Chinese Statistical Yearbook (2003), R&D general investigations in 1999, 2000, 2001 and 2002, and the manufacture investigation in 2004. Some sectors are combined as one sector for convenience here, thus the input-output tables include 38 sectors in the computation in this paper, but there are some differences between 1997 and 2002 (See in Appendix A)

4. The Results

On the base of 38 sectors Chinese input-output tables in 1997 and 2002, R&D-flow-coefficients-matrix, $C_{R\&D}$ and $D_{R\&D}$ are computed. The indexes $MC_{R\&D}$, $SC_{R\&D}$, $MD_{R\&D}$ and $SD_{R\&D}$ are computed on the base of $C_{R\&D}$ and $D_{R\&D}$. It is not necessary to list matrixes $C_{R\&D}$ and $D_{R\&D}$ completely to analyze inter-industry R&D spillover. Therefore, we just give the detailed results of $MC_{R\&D}$, $MD_{R\&D}$ and analysis of $SC_{R\&D}$ and $SD_{R\&D}$ here. The spillover effects of certain industries to themselves are eliminated in the results. The symbols of the sectors are shown in appendix A.

In table 1 and table 2, $MC_{R\&D}$, the receiving effects, reflects the R&D spillover effect each sector obtained as a beneficiary in 1997 and 2002; in table 3 and table 4, $MD_{R\&D}$, the sending effects, shows the R&D dedication of each sector as a deliverer in 1997 and 2002.

Table1. Receiving Effects of each sector as beneficiary in 1997

Codes of sectors	Symbol of sectors	$MC_{R\&D}$	Codes of sectors	Symbol of sectors	$MC_{R\&D}$
33	Sos	0. 0063	21	Omp	0. 0032
34	Hes	0. 0061	38	Gov	0. 0032
18	Eme	0.0058	22	Esh	0.0031
20	Mie	0.0057	27	Pts	0.0031
11	PrC	0.0056	24	Twp	0.0031
36	Scr	0. 0049	26	Fts	0. 0030

17	Mte	0.0048	9	Smf	0.0030
15	Mtp	0.0043	8	Alf	0.0030
19	Ete	0.0042	7	Tex	0.0030
14	SPm	0.0041	2	Cmp	0.0029
4	Mmd	0.0039	28	Com	0.0028
16	Mac	0.0039	37	Pos	0.0026
35	Edu	0. 0039	12	Chm	0. 0023
23	Gps	0.0038	29	Cat	0.0022
25	Con	0.0037	6	Fbt	0.0021
5	Nmm	0.0036	31	Fii	0.0021
10	PPR	0.0036	1	Agr	0.0021
30	Pat	0.0035	3	Pge	0.0018
13	NMP	0.0035	32	Ree	0.0011

*Note: Ranks by the elements of $MC_{R\&D}$ in descending order.

In table 1, it shows that the social service industry accepts 0.0063 R&D expenditure from other sectors per unit of its final demands, which is the largest among all sectors of the economy. This means that there is derivative 0.0063 units R&D expenditure in all the other sectors to produce one unit of final product in social service industry. It should be noted that most R&D expenditure in social service is used to computer service and software. The second largest receiving effect belongs to the industry of services of health care, sports and social welfare, which is 0.0061. In service industry, besides the social service and health care, the scientific research (0.0049) and the Services of education (0.0039) are also notable for their receiving effects. In manufacturer, Electric machinery and equipment (0.0058), Manufacture of instrument, meters and other measuring equipment (0.0057), petroleum refining and coke making (0.0056), manufacture of transport equipment (0.0048) , metal products (0.0043), electronic and telecommunication equipment (0.0042) and Smelting and pressing of metals (0.0041) and have more R&D spillovers from other sectors than other manufacturer industries. As a mining industry, metals mining and dressing (0.0039) also has higher receiving effect.

Table2. Receiving Effects of each sector as beneficiary in 2002

Codes of sectors	Symbol of sectors	$MC_{R\&D}$	Codes of sectors	Symbol of sectors	$MC_{R\&D}$
20	Mie	0.0122	10	PPR	0.0048
11	PrC	0.0088	33	Pos	0.0048
15	Mtp	0.0085	35	Edu	0.0047
18	Eme	0.0085	9	Smf	0.0047
27	ICS	0.0085	7	Tex	0.0044
16	Mac	0.0077	12	Chm	0.0043
32	Scr	0.0076	24	Twp	0.0043
17	Mte	0.0073	2	Cmp	0.0042
25	Con	0.0071	28	Com	0.0042
19	Ete	0.0068	37	Cse	0.0040

34	Oss	0.0065	22	Esh	0.0040
23	Gps	0.0058	21	Omp	0.0040
13	NMP	0.0053	38	Pas	0.0037
4	Mmd	0.0053	3	Pge	0.0035
8	Alf	0.0053	6	Fbt	0.0031
36	Hcs	0.0053	29	Cat	0.0030
14	SPm	0.0053	30	Fii	0.0028
5	Nmm	0.0052	1	Agr	0.0026
26	TSP	0.0048	31	Ree	0.0018

Compared with the results in 1997, the receiving effect of industries in 2002 is much higher on average. There are also some differences in the industries with higher receiving effects. The effect of the industry of Manufacture of instrument, meters and other measuring equipment is 0.0122, ranking first among all the 38 industries. The second and third one is the industries of petroleum refining and coke making (0.0088), and metal products (0.0085). Electric machinery and equipment (0.0085), Manufacture of transport equipment (0.0073), and electronic and telecommunication equipment (0.0068) continue their notable effects, compared with the results in 1997. The effect of Machinery industry (0.0077) becomes higher than 1997. In service industries, Information transmission, Computer services and software (0.0085), Scientific research (0.0076), and Other social services (0.0065) have higher receiving effects than other service industries. Generally, the effect of manufacture becomes more remarkable than in 1997.

Table 3 Sending effects of each sector per unit of its final demand as deliverer in 1997

Codes of sectors	Symbol of sectors	Elements of $MD_{R\&D}$	Codes of sectors	Symbols of sectors	Elements of $MD_{R\&D}$
36	Scr	0.3157	2	Cmp	0.0007
20	Mie	0.0355	15	Mtp	0.0007
3	Pge	0.0281	30	Pat	0.0006
12	Chm	0.0131	13	NMP	0.0005
4	Mmd	0.0127	7	Tex	0.0004
37	Pos	0.0084	34	Hes	0.0004
19	Ete	0.0082	10	PPR	0.0004
11	PrC	0.0073	31	Fii	0.0003
17	Mte	0.0065	1	Agr	0.0002
16	Mac	0.0064	21	Omp	0.0001
22	Esh	0.0048	8	Alf	0.0000
14	SPm	0.0038	32	Ree	0.0000
35	Edu	0.0035	25	Con	0.0000
27	Pts	0.0027	5	Nmm	0.0000
33	Sos	0.0018	9	Smf	0.0000
23	Gps	0.0013	24	Twp	0.0000
26	Fts	0.0011	28	Com	0.0000

6	Fbt	0.0009	29	Cat	0.0000
18	Eme	0.0008	38	Gov	0.0000

*Note: Ranks by the elements of $MD_{R\&D}$ in descending order.

From table 3, the largest R&D spillover effect to other sectors by producing one unit of final product (the sending effect) is the sector of scientific research, and the effect is 0.3157, which is much larger than other sectors. The reason lies in the production purpose of scientific research. In China, a large part of R&D resources is in this sector. In mining and quarrying, petroleum and natural gas extraction (0.0281), metals mining and dressing (0.0127) have very large R&D spillover flowing to other sectors. In manufacturer branches, Manufacture of instrument, meters and other measuring equipment (0.0355), chemicals industry (0.0131), Electronic and Telecommunication Equipment (0.0082), Petroleum refineries and coke-making (0.0073), Manufacture of transport equipment (0.0065), and machinery industry (0.0064) have relatively large R&D spillover effect on other sectors. In tertiary industry branches, besides scientific research, polytechnic services (0.0084) has large R&D spillover effect on other sectors, compared with other branches.

Table 4 Sending effects of each sector per unit of its final demand as deliverer in 2002

Codes of sectors	Symbol of sectors	Elements of $MD_{R\&D}$	Codes of sectors	Symbols of sectors	Elements of $MD_{R\&D}$
32	Scr	0.2736	15	Mtp	0.0019
3	Pge	0.0374	26	TSP	0.0017
4	Mmd	0.0278	23	Gps	0.0015
18	Eme	0.0171	6	Fbt	0.0010
19	Ete	0.0158	9	Smf	0.0010
33	Pos	0.0133	2	Cmp	0.0009
14	SPm	0.0129	36	Hcs	0.0008
17	Mte	0.0124	34	Oss	0.0006
20	Mie	0.0116	1	Agr	0.0004
12	Chm	0.0092	8	Alf	0.0003
16	Mac	0.0071	30	Fii	0.0001
27	ICS	0.0062	25	Con	0.0000
22	Esh	0.0056	31	Ree	0.0000
11	PrC	0.0036	5	Nmm	0.0000
13	NMP	0.0032	24	Twp	0.0000
35	Edu	0.0028	28	Com	0.0000
10	PPR	0.0024	29	Cat	0.0000
7	Tex	0.0022	37	Cse	0.0000
21	Omp	0.0019	38	Pas	0.0000

Compared with the results in 1997, the effect of scientific research (0.2736) continues to be the first largest one, but decreases. In mining and quarrying, the sending effects of petroleum and natural gas extraction (0.0374), metals mining and dressing (0.0278) increases compared with 1997. Electric machinery and equipment (0.0171) becomes one of the most notable industries for its large increase in sending effect, from 0.0008 to 0.0171. Smelting and pressing of metals (0.0129) also has a remarkable increase. Electronic and Telecommunication Equipment (0.0158) Manufacture of transport equipment (0.0124), Manufacture of instrument, meters and other measuring equipment (0.0116), and chemicals industry (0.0092) continue their important roles in sending effect in 1997. In tertiary industry branches, besides scientific research, polytechnic services (0.0133) still has large R&D spillover effect on other sectors. Information transmission, Computer services and software (0.0062) has much more effect compared with other branches.

The representative columns (sectors) of $SC_{R\&D}$ indicate the origins of R&D expenditure flow of the receiving sectors. For example, the results show that for agriculture, in the total R&D spillover it accepts, 45 percent is from chemicals in 1997, and the proportion decreases to 26 percent in 2002. Next is scientific research, about 6 percent in 1997, and 13 percent in 2002, which is a large increase. The proportion of Polytechnic services is also about 6 percent in 1997, and becomes 5 percent in 2002. For metals products in manufacture, 22 percent of R&D spillover it accepts is from chemicals, 17 percent is from smelting and pressing of metals, 9 percent is from scientific research, 8 percent is from machinery industry. While in 2002, 37 percent of the receiving effect that metals products obtained is from smelting and pressing of metals, 12 percent is from scientific research, and 7 percent is from chemicals.

By the integrated analysis of $MC_{R\&D}$, $MD_{R\&D}$, $SC_{R\&D}$ and $SD_{R\&D}$, we can find the main flowing directions of the R&D spillovers. The main results of 1997 and 2002 are shown in Chart 1 and Chart 2 respectively. The industries in the frame with real line are the main sending industries of R&D spillover, while those in the frame with dashed line are the main receiving industries of R&D spillovers. From Chart 1 and Chart 2, we can see that the main sectors related with R&D spillover are divided into 3 groups. The sectors located both in the frame with real line and the frame with dashed line have large sending effect and receiving effect at the same time. The sectors located just in the frame with real line have high sending effect only, and sectors located just in the frame with dashed line have great receiving effect only.

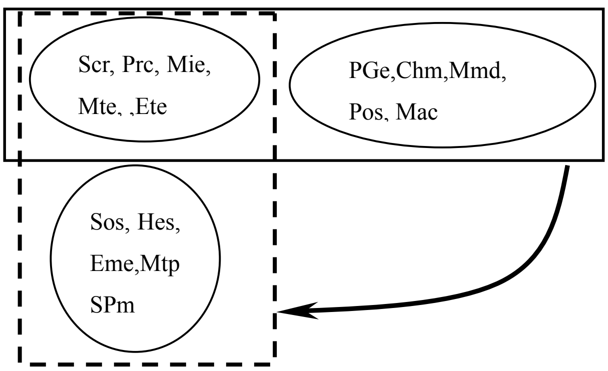

Chart 1 The main flowing directions of R&D spillovers effects in 1997

From Chart 1, we can find that in 1997, the sectors with high sending and receiving effects simultaneously include scientific research, Petroleum refineries and coke-making, Manufacture of instrument, meters and other measuring equipment, Manufacture of transport equipment, and Electronic and Telecommunication Equipment. The sectors only with high sending effect include Petroleum and natural gas extraction, Chemical industry, Metals mining and dressing, Polytechnic services, and Machinery industry. The sectors only with high receiving effect are Social services, Services of health care, sports and social welfare, Electric machinery and equipment, Metal products, and Smelting and pressing of metals.

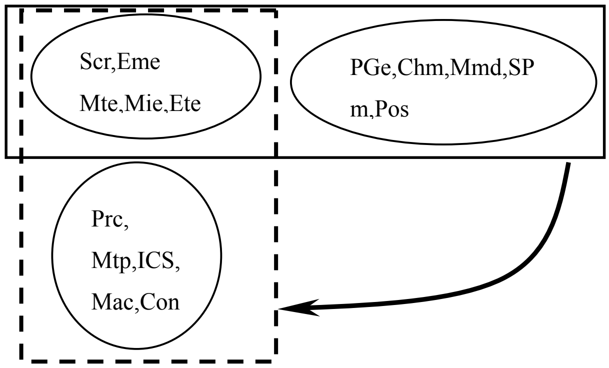

Chart 2 The main flowing directions of R&D spillovers effects in 2002

Compared with the results in 2002, it shows that Electric machinery and equipment becomes the sector with both high sending and receiving effect, instead of Petroleum refineries and coke-making. The industry of Smelting and pressing of metals is s sector with high sending effect now, while in 1997, it is a sector with high receiving effect. The Machinery industry is a sector with high sending effect in 1997, and becomes a sector with high receiving effect in 2002. Petroleum refineries and coke-making has high receiving effect only in 2002, while in 1997, it is a sector with both high sending and receiving effect. In 2002, Information transmission, Computer services and software, and construction enter the group with high receiving sectors, compared with 1997. But it should be noted that the industry of social services in 1997 includes computer services.

5. Summary and conclusion

In this paper, we introduced backward R&D-flow-coefficients-matrix and forward R&D-flow-coefficients-matrix, and defined the sending and receiving effect on the base of the two matrixes. The inter-industry R&D effect are computed and analyzed by using the method and the Chinese input-output tables of 1997 and 2002. The results of the two periods are compared, and we analyze the change of R&D spillovers in China from 1997 to 2002.

Besides R&D expenditure, other indicators can also be used in the analysis, such as patents, scientists or specialists, and so on. The method is just used to analyze the inter industry flowing of R&D spillover, and we can’t compute the contribution of R&D activities to the productivity growth.

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Appendix A

Sectors of input-output table in 1997

Codes	Name	Symbols
1	Agriculture,forestry and fishing	Agr
2	Coal mining and processing	Cmp
3	Petroleum and natural gas extraction	Pge
4	Metals mining and dressing	Mmd
5	Nonmetal minerals mining and dressing	Nmm
6	Food, beverages and tobacco	Fbt
7	Textile industry	Tex
8	Wearing apparel, leather, furs, down and others	Alf
9	Sawmills and manufacture of furniture	Smf
10	Paper products, printing and record medium reproduction	PPR
11	Petroleum refineries and coke-making	PrC
12	Chemical industry	Chm
13	Non-metal mineral products	NMP
14	Smelting and pressing of metals	SPm
15	Metal products	Mtp
16	Machinery industry	Mac
17	Manufacture of transport equipment	Mte
18	Electric machinery and equipment	Eme
19	Electronic and Telecommunication Equipment	Ete
20	Manufacture of instrument, meters and other measuring equipment	Mie
21	Other manufacturing Products	Omp

22	Electricity, steam and hot water production and supply	Esh
23	Production and supply of gas	Gps
24	Production and supply of tap water	Twp
25	Construction	Con
26	Freight transportation and storage	Fts
27	Post and telecommunication services	Pts
28	Commerce	Com
29	Catering services	Cat
30	Passenger transport	Pat
31	Finance and insurance	Fii
32	Real estate industry	Ree
33	Social services	Sos
34	Services of health care, sports and social welfare	Hes
35	Services of education, culture and arts radio, film and television	Edu
36	Scientific research	Scr
37	Polytechnic services	Pos
38	Government agencies and others	Gov

Sectors of input-output table in 2002

Code	Name	Symbol
1	Agriculture,forestry and fishing	Agr
2	Coal mining and processing	Cmp
3	Petroleum and natural gas extraction	Pge
4	Metals mining and dressing	Mmd
5	Nonmetal minerals mining and dressing	Nmm
6	Food, beverages and tobacco	Fbt
7	Textile industry	Tex
8	Wearing apparel, leather, furs, down and others	Alf
9	Sawmills and manufacture of furniture	Smf
10	Paper products, printing and record medium reproduction	PPR
11	Petroleum refineries and coke-making	PrC
12	Chemical industry	Chm
13	Non-metal mineral products	NMP
14	Smelting and pressing of metals	SPm
15	Metal products	Mtp
16	Machinery industry	Mac
17	Manufacture of transport equipment	Mte
18	Electric machinery and equipment	Eme
19	Electronic and Telecommunication Equipment	Ete
20	Manufacture of instrument, meters and other measuring equipment	Mie

21	Other manufacturing Products	Omp
22	Electricity, steam and hot water production and supply	Esh
23	Production and supply of gas	Gps
24	Production and supply of tap water	Twp
25	Construction	Con
26	Transportation，storage and post	TSP
27	Information transmission, Computer services and software	ICS
28	Commerce	Com
29	Catering services	Cat
30	Finance and insurance	Fii
31	Real estate industry	Ree
32	Scientific research	Scr
33	Polytechnic services	Pos
34	Other social services	Oss
35	Services of education	Edu
36	Services of health care and social welfare	Hcs
37	culture, sports, and entertainment	Cse
38	Public administration and social organization	Pas