Double Filtering Method and Its Application: A Fundamental Economic Structure in the Development of China, Japan and USA

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Abstract: The paper established a Double Filtering Method (DFM) to visualize the skeleton industrial structure (SIS) of one economy and find its evolution rule. Different with the previous researches, this method is from a new view of industrial conjunctions combined by leading sectors to depict the industrial structure. It can be proved that the leading sector selected by DFM must be key sector selected by Hirschman Method. Applied DFM to China, Japan and USA, the results showed that DFM could scratch SIS of each economy with its own characteristics, visualize the general evolution rules of the industrial structure with crisscrossed conjunctions among leading sectors. The complexity and sensitivity analysis of SIS showed that the adjustment of SIS in USA had matched with the requirement of its economic growth from 1972 to 1998. Whilst to Japan and China, their adjustments of SIS had not so effectively promoted their economic growth. To China, though the conjunctions among leading sectors were strengthened (it also means the inputs increased), the inputs was not so efficiency especially during 1995-1999. It is necessary for China to promote investments that are more productive, especially those embodied with

technology.

Keywords: Double filtering method; Skeleton industrial structure; Evolution rule; Economic growth; Input-output analysis

1. Introduction

The industrial structure evolution is one of the basic propositions of development economics. The modern history of economic development shows that the process of economic development of a country, is not only for the growth of the total economy, but also is accompanied by the evolution of the industrial structure. Especially in the middle stage of industrialization, the accelerated transformation of industrial structure is the important characteristic of economic growth. Finding the evolution rule of the industrial structure will be helpful to find ways to improve the stability of the regional economic growth.

Since the 1960s, series theories of industrial structure evolution appeared. From Hoffman's law (1931), Petty-Clark Law (1940) to the study of changes in the trend of Kuznets (1946), then to input-output analysis of Leontief (1953), Chenery's ‘standard configuration’(1960) and ‘flying geese form’ provided by Kiyoshi Kojima (2000) and so on. These theories demonstrated that the development and evolution of the industrial structure had its own laws on the whole. They can be summarized as follows. From the perspective of the three industries conversion, there exists a declining trend of the first industry in terms of employment and output. The share of the secondary industry is growing rapidly first, then tends to stable. The share of the tertiary industry has been growing by the presence of ‘One, two, three’ to ‘three, two, one' change trend. From the point of view of industrialization stage of development, the evolution of the industrial structure can be divided into five stages, pre-industrial era, the beginning of industrialization, the mid-industrialization, the late and post-industrialization era. From the perspective of leading industries, the leading industry replacement in order usually was agriculture, textile industry, heavy industry, low processing and assembly industries, highly processing and assembly industries, the tertiary industry, the information industry.

We all know that there are complex supply and demand conjunctions among all industries. This determines that the development of a particular industry would inevitably have impacts on many other associated industries. Interrelationship among all industries reflects the technical economic ties among them. It is also the interdependence, mutual restraint relationships among all industries in the process of social reproduction. It gives a deep view of industrial structure. To examine the industrial structure evolution, the research cannot be confined among the three industries and separated leading industries. It should be further inspected from the industrial system, and examine the conjunctions among all the industries. There was seldom such kind of research (Stanley J. Feldman *et. al.*, 1987). Except Hermann Schnabl (2001) provided Minimum Flow Analysis (MFA) method to describe the law of the industrial structure changes during 1980-1990 in Germany, USA and Japan. One disadvantage of MFA is the filter value will affect the accuracy of the conclusions. There is no criterion to decide the fit filter value. The other disadvantage is MFA using Boolean algebra method to determine the values of the incidence matrix, which could not reflect the conjunction strength among all the industries reasonably.

Based on the existing research, overcoming disadvantages of MFA, the paper provided a Double Filtering Method (DFM) to visualize the skeleton industrial structure (SIS) of one economy and find its evolution rule from the perspective of industrial conjunctions and applied it to China, Japan and USA.

The paper is organized as below. Section 2 gives the steps of DFM. Section 3 describes the data source. Section 4 shows application results. Section 5 makes complexity and sensitivity analysis. Section 6 provides conclusions and suggestions.

2. Double Filtering Method

Step1. From IO table, one can get $T = A < X >$ (1)

Where T represents the intermediate flow matrix, A means direct input coefficient matrix, $< X >$ means the diagonal matrix of X, while

$$X = (I - A)^{-1} Y = (I + A + A^2 + A^3 + \cdots) Y \tag{2}$$

Input (2) to (1),

$$T = A < (I + A + A^2 + A^3 + \cdots)Y >= A < Y > + A < AY > + A < A^2 Y > + \cdots \tag{3}$$

Where $< Y >$ means the diagonal matrix of final demand Y， $< AY >$ means the diagonal matrix of AY .

Set $L^0 = A < Y >$, $L^1 = A < AY >$, $L^2 = A < A^2 Y >$, $L^3 = A < A^3 Y >$ . . .

Get $LD^s = L^s - diag(L^s)$ $(s = 0,1 \cdots K)$

For any element of A is smaller than 1, there will exist a number K, $LD^K \to 0$.

Step2. Set the first threshold $F1 = \frac{1}{K+1} \cdot \sum_{s=0}^{K} \frac{1}{n^2} \sum_{i=1}^{n} \sum_{j=1}^{n} l_{ij}^s$ (4)

Step3. Get the incidence matrix W^0, W^1, W^2, W^3 . . . W^K of $LD^0, LD^1, LD^2, LD^3 \cdots$ with

$w_{ij}^{s} = \begin{cases} 1 & ld_{ij}^{s} \geq F1 \\ 0 & the \quad other \end{cases}$, ld_{ij}^{s} is the element of matrix LD_s.

Step4. Calculate D=(d_{ij})， D=$W^0 + W^1 + W^2 + W^3 + \cdots W^K$ (5)

Step5. Calculate E=(e_{ij}),

$$e_{ij} = d_{ij} /(K+1) \tag{6}$$

Step6. Set the second threshold F2=$\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} e_{ij} = \frac{1}{K+1} \cdot \frac{1}{n^2} \sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij}$ (7)

Step7. Set the incidence matrix F=$(f_{ij})$of E, $f_{ij} = \begin{cases} 1 & e_{ij} \geq F2 \\ 0 & the \quad other \end{cases}$,

Step8. Calculate G=(g_{ij}),

$$g_{ij} = f_{ij} + f_{ji} \tag{8}$$

F matrix is a 0-1 matrix, the elements of G only have three possible value 0，1 or 2. If g_{ij} =0， means the conjunction between i and j is weak. If g_{ij} =1, then $f_{ij} = 1$ (or $f_{ji} = 1$). This means that if the total output of all sectors increased one unit, the intermediate input of sector j to sector i (or the intermediate use of sector j from sector i) will have an increase greater than the average level. If g_{ij} =2, this means that if the total output of all sectors increased one unit, not only the intermediate input of sector j to sector i but also the intermediate use of sector j from sector i will have an increase greater than the average level.

Step9. If g_{ij} =2， sector i and sector j were called as **leading sectors**. The network combined by the conjunctions among all the leading sectors was called as **the skeleton industrial structure (SIS)**.

To make up the defect that one filtering value may cause poor deviation, two filtering threshold were set in the algorithm. So the method was called as Double

Filtering Method. In Step3, D matrix was obtained by numerical summation, not by the method of Boolean algebra, the conjunction strength among all sectors was fully reflected by the elements value of matrix D. It can be proved that the leading sector selected by DFM must be key sector selected by Hirschman Method.

Theorem 1. The leading sector selected by Double Filtering Method must be key sector selected by Hirschman Method.

Prove：From the steps of DFM method，if j_0 is a leading sector, then

$$a_{ij_0} > \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij} \qquad (9) \qquad\qquad b_{ik}a_{kj_0} > \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ik}a_{kj} \qquad (10)$$

While $b_{ij_0} = a_{ij_0} + \sum_{k=1}^{n} b_{ik}a_{kj_0}$, from equations(9) and (10),

$$b_{ij_0} > \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij} + \sum_{k=1}^{n} b_{ik}a_{kj_0} \Rightarrow \sum_{i=1}^{n} b_{ij_0} > \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij} + \sum_{i=1}^{n}\sum_{k=1}^{n} b_{ik}a_{kj_0}$$

$$\Rightarrow \frac{1}{n}\sum_{i=1}^{n} b_{ij_0} > \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij} + \frac{1}{n}\sum_{i=1}^{n}\sum_{k=1}^{n} b_{ik}a_{kj_0}$$

$$> \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij} + \frac{1}{n}\sum_{i=1}^{n}\sum_{k=1}^{n}\left(\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ik}a_{kj}\right) \quad \text{(from equation(10))}$$

$$= \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij} + \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{n} b_{ik}a_{kj} = \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n}\left(a_{ij} + \sum_{k=1}^{n} b_{ik}a_{kj}\right) = \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij} \qquad (11)$$

According to the definition of key sector by Hirschman (1958), if j_0 is a key sector by Hirschman definition, then $\frac{1}{n}\sum_{i=1}^{n} b_{ij_0} > \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}$. Equation (11) shows that j_0 is satisfied with the Hirschman definition.

Hirschman method determined the conjunction strength among all sectors from the view of the total consumption coefficient. Some sector may have strong conjunction with several specific sectors (the value of some $b_{i,j}$ is big) but have very weak conjunction with many other sectors, which means the scope of their influence is not widespread, but these sectors were selected as key sectors. The double filtering method examined the conjunction strength of a sector with the other sectors from the respect of the direct consumption and each layer of indirect consumption. And self-dependent effect which was usually much big was eliminated. Compared with Hirschman method, DFM has much stronger determining ability. The key sectors determined by Hirschman method may not be the leading sectors determined by DFM.

3. Data Source

In this paper, China input-output tables in 1981 with 26 sectors, in 1987 with 35 sectors, in 1992, 1995 with 33 sectors, in 1997, 1999 with 40 sectors were published by China Statistics Bureau. The USA input-output tables in 1972, 1977, 1982, 1985 and 1990 with 36 sectors and in 1998 with 85 sectors; Japan input-output tables in 1970, 1975, 1980, 1985, 1990, 1995 with 36 sectors and in 2000 with 50 sectors were published by OECD. The sector classification and statistical coverage of these input-output tables are inconsistent, to make longitudinal study of a national industrial structure and the horizontal comparison of different national industrial structure, it is necessary to re-compile the input-output tables with a common sector classification and consistency of statistical coverage.

During 1992-1995, World Bank carried out ‘The greenhouse gas emission control and countermeasures’ project, taking into account the comparability of China annual input-output table, the original input-output tables of China were re-compiled into 18 sectors which emphasized on energy sectors. Referred to this 18 sector classification defined by World Bank and the three industries zoning regulations issued by China Statistics Bureau No.14 document in 2003, taking into account the merge and split feasibility of the existing input-output table, the national economy is divided into another kind of 18 sectors (See Table 1). In this version, the traditional industries of the food industry, textile industry, sewing and leather manufacturing and paper and stationery industry sectors were merged into 1 sector- Food, Textile, Paper-making and Furniture; Machinery industry with high technical content was subdivided into Machinery Industry, Transportation Equipment Manufacturing, Electronics and Electrical Equipment Manufacturing, Instrumentation Office Machinery and other. This is conducive to study the development rule and trends of high-tech industry (Xiuli Liu, Xikang Chen, 2005). With the sector classification in Table 1, input-output tables of China, Japan and USA were re-compiled at current price.

4. Applications

With the re-compiled input-output tables for the three economies, applied the DFM method, their SIS during about 30 years were obtained (See Figures 1-19). The core of the SIS of USA in 1972 was sector 5 (Food textile and paper making furniture industry), the same as that of Japan in 1970. After the industrial structure evolution to the higher stage, Sector 18 (Other Services) became the core of the SIS of USA and Japan in 1998 and in 2000. The gravity of the manufacturing sector is gradually transferred to the High Technological Industry (sector 12, 14). The role of the tertiary industry (sector 18) became more and more prominent. The delay change of SIS during 1980-1990 mainly made Japan fell into the worst postwar recession. The SIS of China from 1981 to 1995 was relatively simple. The connections among industries were not as strong as those in Japan and USA. Sector 5 became the core of the SIS of China in 1987. The role and the impacts of Sector 18 became more and stronger in China.

The bilateral conjunctions between Sector 1 and Sector 5, between Sector 5 and Sector 18 were in each SIS of USA and Japan. These showed that even to the industrialized economy, these bilateral conjunctions were the base part of its SIS. These sectors appeared in each SIS of China, but the bilateral conjunctions between Sector 5 and Sector 18 didn't exist in 1981 and 1997.

5. Complexity and Sensitivity Analysis

Here Complexity Index ($\mathrm{CI_t}$) of SIS is defined as,

$$\mathrm{CI_t} = (\mathrm{ln_t} * 2 + \mathrm{s_t})/100 \quad (12)$$

where $\mathrm{ln_t}$ is the number of lines in the SIS in year t, $\mathrm{s_t}$ is the number of sectors in the SIS in year t.

The elasticity coefficient (e) of GDP growth rate to SIS is defined as,

$$\mathrm{e} = (\mathrm{CI_{t2}} - \mathrm{CI_{t1}})/(\mathrm{r_{t2}} - \mathrm{r_{t1}})/100 \quad (13)$$

where $\mathrm{r_{t1}}$ is the real GDP growth rate at time t1, $\mathrm{r_{t2}}$ is the real GDP growth rate at time t2. e is used to evaluate the sensitivity of GDP growth rate to SIS.

Calculated CI for each SIS of three economies (Figures 1-19) with equation (12), compared the change of $\mathrm{CI_t}$ and the real GDP growth rate for each economy (See

Figures 20-22), it is found that, if CI_{t1}<CI_{t2}, there must be a turn point of real GDP growth rate during time t1 to t2 around. If $CI_{t1} \geq CI_{t2}$, the growth rate of real GDP during time t1 to t2 is positive and without obvious fluctuations. For example, to USA, from 1977 to 1982 CI decreased from 27 to 18, the growth rate of real GDP in 1982 was -1.94%, in 1983 was 4.52%. The growth rate of real GDP in 1982 was a turn point (See Figure 20). To Japan, from 1970 to 1975, CI decreased from 20 to 16, there was a turn point in 1974, the growth rate of real GDP in 1974 was -1.2% (See Figure 21).

To the elasticity coefficient, it is found that all the value of e in USA was greater than 0 (See Figure 20). It means that the change of GDP growth rate and the complexity change of SIS were in the same direction. The adjustment of SIS in USA had matched with the requirement of its economic growth. Whilst to Japan and China, the results were very different. Except in 1990, the value of e was negative for Japan, especially in 1980, e=-6.67 (See Figure 21). In China, all the value of e was smaller than or equal to 0, especially in 1997, e=-4.93(See Figure 22). These meant that the adjustment of SIS of Japan and China at that time period when e≤0 was not very effectively, it didn't promote its economic growth.

To China, especially from 1995 to 1999, CI increased from 19 to 34. But its real GDP growth rate was down year by year from 10.92% to 7.62%. This implied that though the conjunctions among sectors were strengthened (it also means the inputs increased), the inputs was not so efficiency during 1995-1999. The following researches support this opinion. Yanrui Wu (2000) found that China's economic growth in the 1980s was mainly due to efficiency improvement and growth in inputs. This has however changed in the 1990s. Technological progress has now become an important factor propelling China's economic growth. However, the growth potential in efficiency was almost exhausted by the middle of the 1990s. Xiaoying Wu (2012) showed that the marginal product of capital of China from 1979 to 2009 was decreased 1.9% yearly. After 1995 with the background of Asian financial crisis, the decreased speed was 2.3% or greater, which was astonishingly. Kui-Wai Li and Tung Liu (2011) found that input growth is the major contributor to economic growth in the post-reform China. China’s economic growth was not so efficiency in the post-reform period especially during 1995-1999. Shiyi Chen *et al.* (2011) indicated that the structural change and corresponding factor reallocation has contributed decreasingly to productivity since 1992.

6. Conclusions and suggestions

The paper established a Double Filtering Method (DFM) to visualize the skeleton industrial structure (SIS) of one economy and find its evolution rule. Different with the previous researches, this method is from a new view of industrial conjunctions combined by leading sectors to depict the industrial structure. It overcame the disadvantages of MFA. It can be proved that the leading sector selected by DFM must be key sector selected by Hirschman Method. The application showed that DFM could scratch the skeleton industrial structure of one economy, describe the general rules of the industrial structure evolution visualized with more detailed conjunctions among leading sectors. Complexity change of SIS could imply the turn point of economic growth. Sensitivity of SIS complexity could evaluate if the SIS had promoted its economic growth.

The applications of DFM also implied that, (1) during the process of SIS adjustment, the inputs efficiency was a key point to decide whether the adjustment could promote its economic growth. It is necessary for China to promote investments that are more productive, especially those embodied with technology. Policies should be geared to improve technical efficiency and utilize resources effectively.

(2) In any stage of industrialization, Agriculture and Food, Textile, Paper-making and Furniture and their connections were the basic part of one economy's SIS. The development of Agriculture and the direct relevant industries should not be ignored. Especially in the background that food security have recently been challenged by emerging forces including climate change, water scarcity, the energy crisis as well as the credit crisis.

(3) Accurate positioning of the leading sectors timely is the key of the economic growth. Relaxed environment for innovation and effective industrial policy ensured the industrial structure upgrade successfully. Since 1990s, America successfully use economic globalization and information technology, timely upgraded and adjusted its industrial structure, found the new engine of the economic growth at the different period and made its economy leading in the world. USA is ahead of Europe and Japan in the development of high-tech. China should further improve the relevant industrial policies to support the upgrade of industrial structure.

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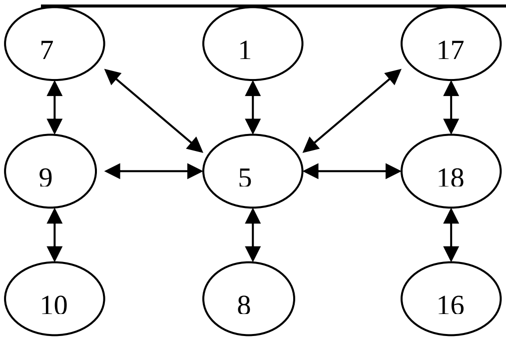
Table 1. Sector Definition of China, Japan and USA Extended Input-Output Tables

Code	Sector Definition	Code	Sector Definition
1	Agriculture	10	Machinery Industry
2	Coal Mining	11	Transportation Equipment

			Manufacturing
3	Oil and Gas Exploration	12	Electronics and Electrical Equipment Manufacturing
4	Other Mining industry	13	Instrumentation Office Machinery and other
5	Food, Textile, Paper-making and Furniture	14	Electricity, Gas , Water Production and Supply
6	Petroleum Processing and Coking industry	15	Construction
7	Chemical Industry	16	Transportation, Post and Storage
8	Construction Materials, etc	17	Commercial and Catering industry
9	Metal Smelting and Fabricated Metal products	18	The Other Services



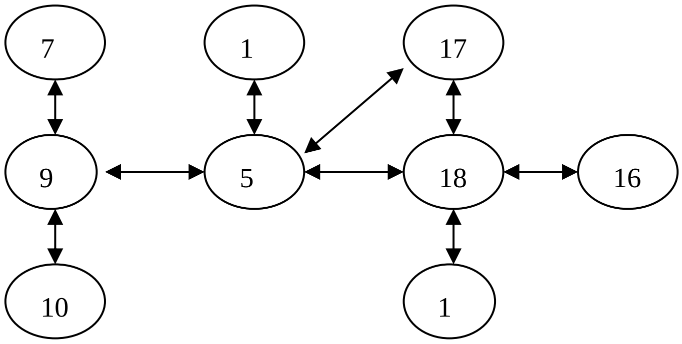


Figure 1. ISI of USA in 1972

Figure 2. ISI of USA in1977

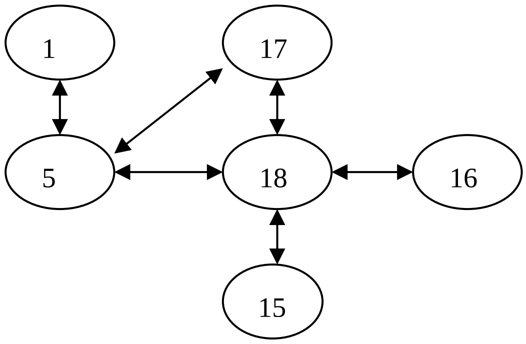


Figure 3.　ISI of USA in 1982

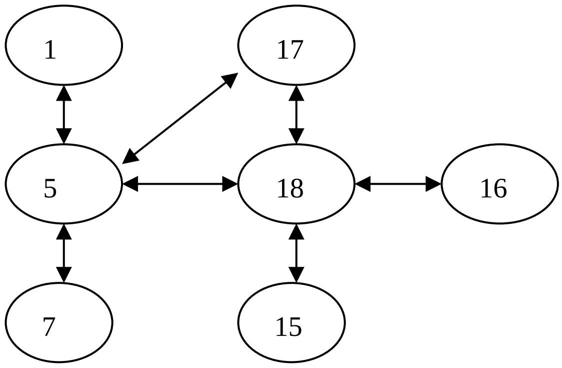


Figure 4. ISI of USA in 1985

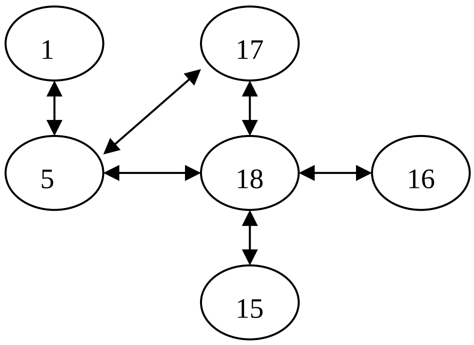


Figure 5. ISI of USA in 1990

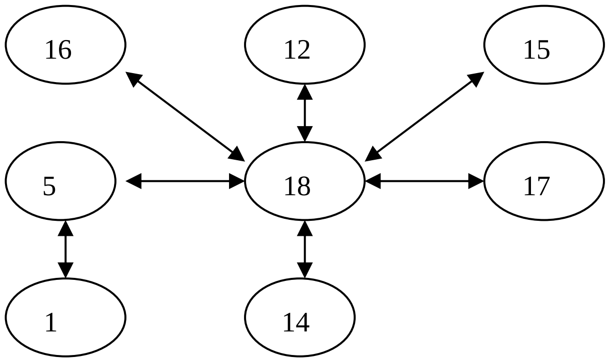


Figure 6. ISI of USA in 1998

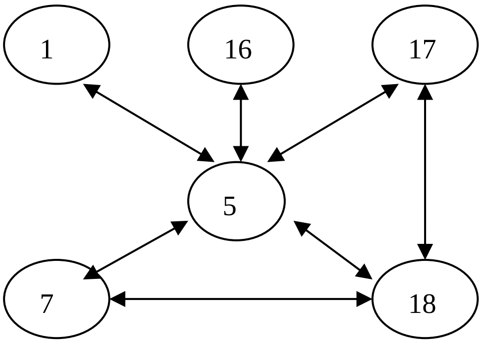


Figure 7. ISI of Japan in 1970

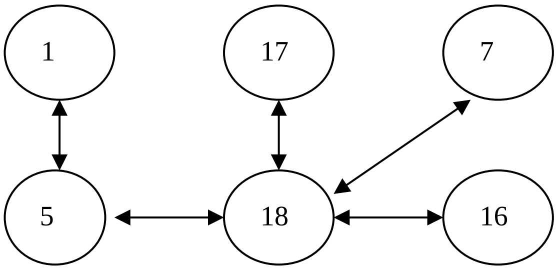


Figure 8. ISI of Japan in 1975

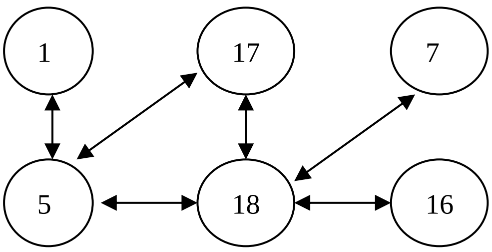


Figure 9. ISI of Japan in 1980

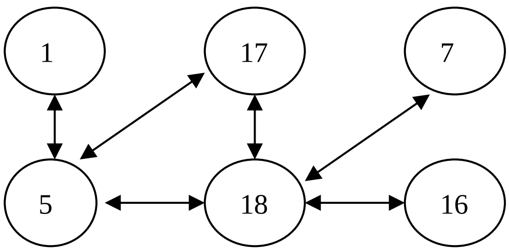


Figure 10. ISI of Japan in 1985

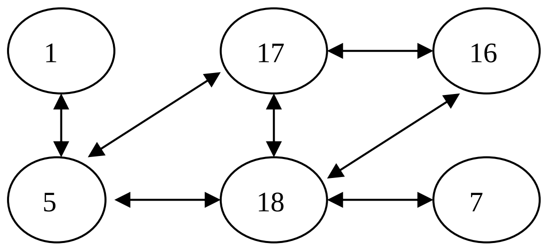


Figure 11. ISI of Japan in 1990

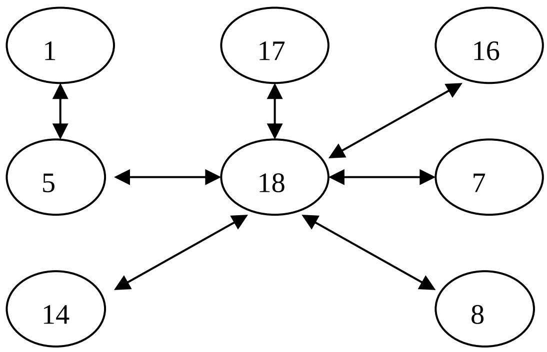


Figure 12. ISI of Japan in 1995

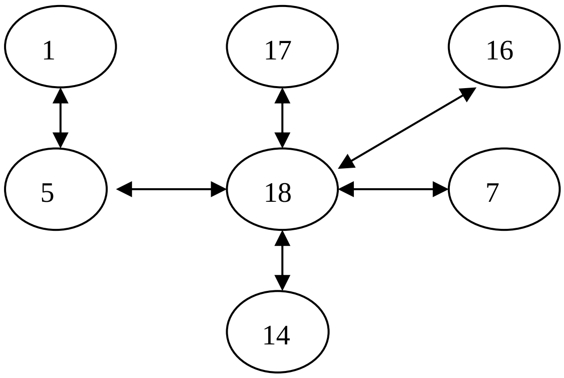


Figure 13. ISI of Japan in 2000

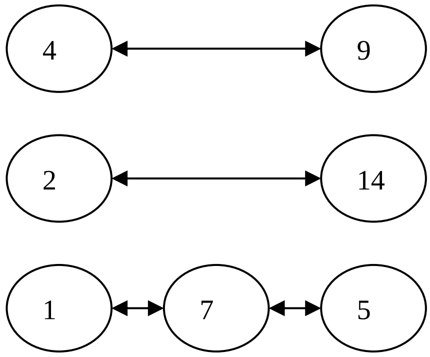


Figure 14. ISI of China in 1981

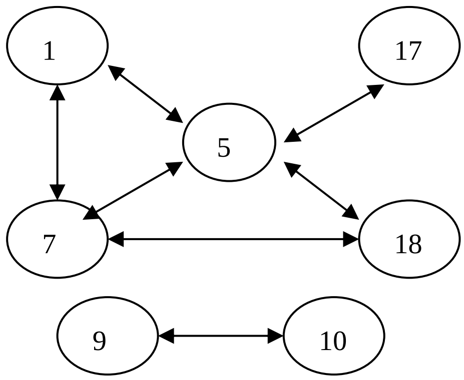


Figure 15. ISI of China in 1987

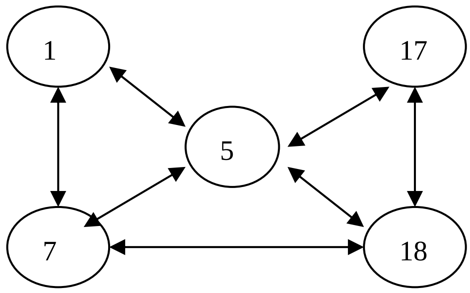


Figure 16. ISI of China in 1992

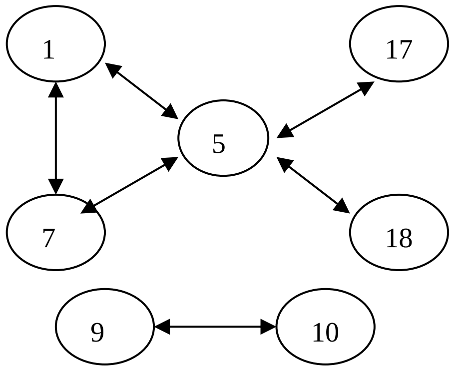


Figure 17. ISI of China in 1995

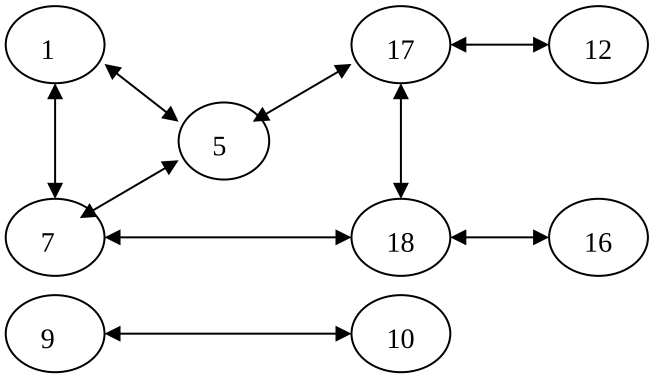


Figure 18. ISI of China in 1997

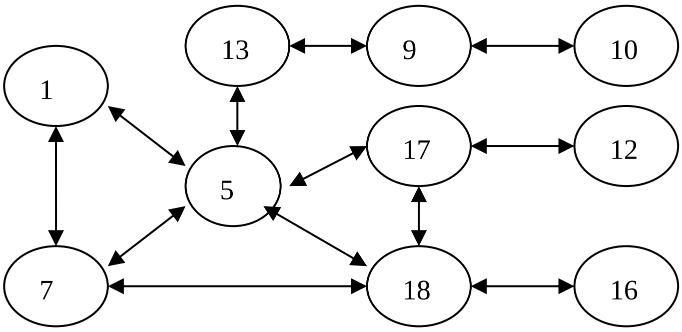


Figure 19. ISI of China in 1999

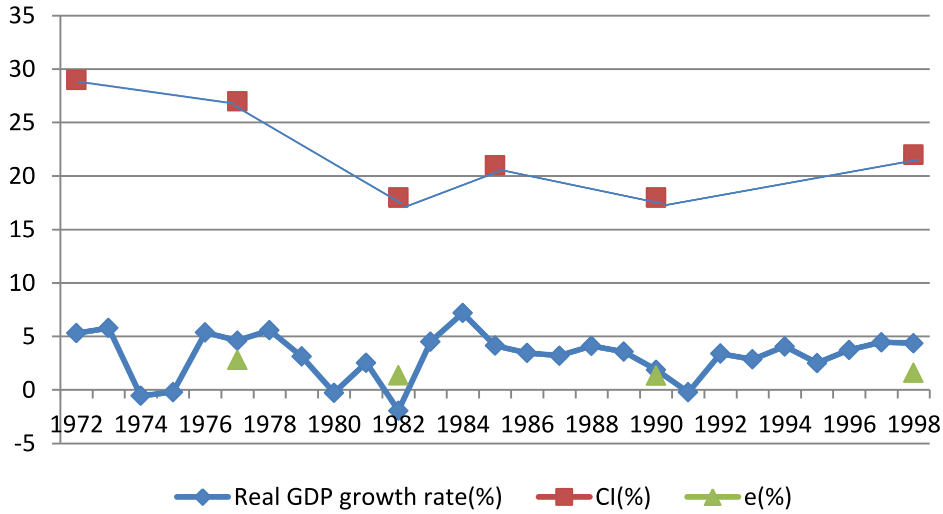


Figure 20. Real GDP growth rate, CI and e of USA

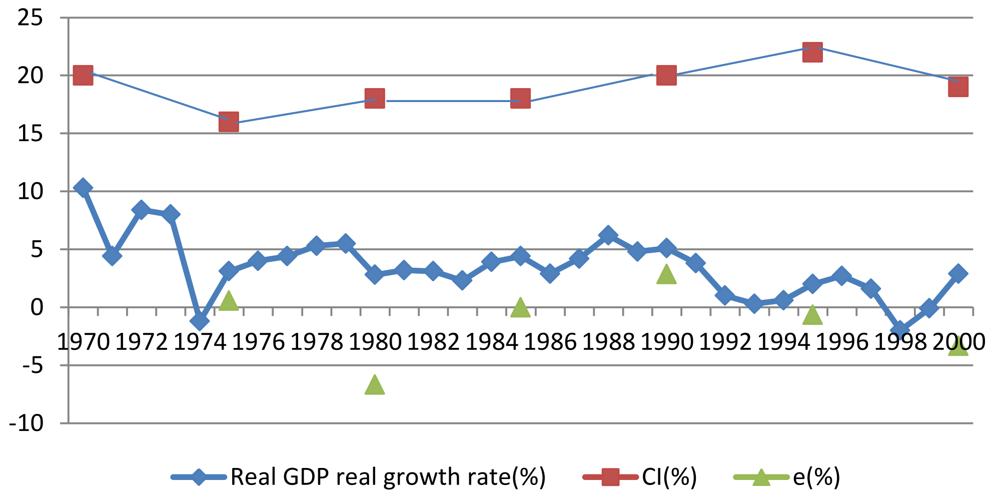


Figure 21. Real GDP growth rate, CI and e of Japan

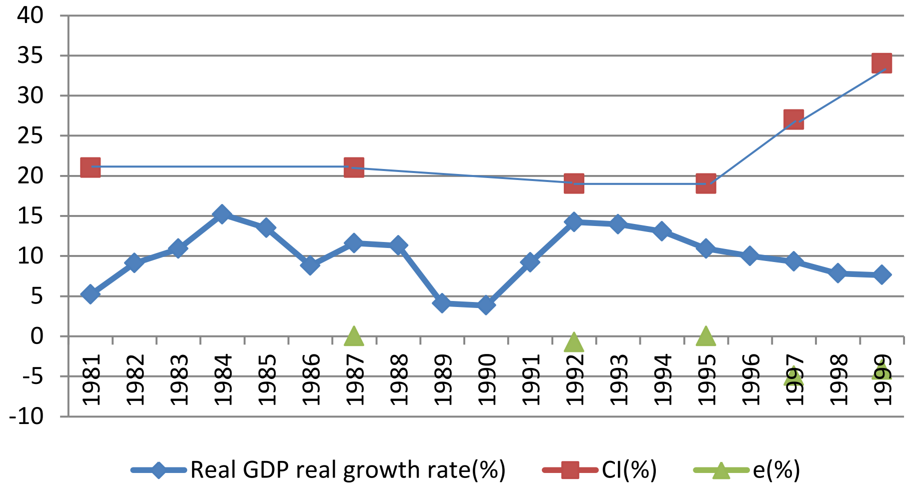


Figure 22. Real GDP growth rate, CI and e of China