Intersectoral Linkages and Key Sectors in China 1987-1997

--An Application of Input-output Linkage Analysis

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1 Introduction

The analysis of linkages, used to examine the interdependency in production structures, has a long history within the field of input-output analysis. Since the pioneering work of Chenery & Watanabe (1958), Rasmussen (1956) and Hirschman (1958) on the use of linkages to compare international productive structures, this analytical tool has been improved and expanded in several ways, and many different methods have been proposed for the measurement of linkage coefficients. The measures, including backward and forward linkages, have extensively been used for the analysis of both interdependent relationships between economic sectors, and for the formation of development strategies (Hirschman, 1958).

In the 1970s, these traditional measures were widely discussed and several adapted forms were put forward (Yotopoulos & Nugent, 1973; Laumas, 1976; Riedel, 1976, Jones, 1976; Schultz, 1977). More recently, linkage analysis methods have again attracted increasing attention from the part of input-output analysts (Cella, 1984; Clements, 1990; Heimler, 1991; Sonis *et al*, 1995; Dietzenbacher, 1997). With regard to the measurement of linkage coefficients, a few different methods have been presented so far, and there exists many differences between these methods. By applying linkage methods to the case of China, this paper makes an attempt at empirically comparing the difference between the results derived from the different methods, and at examining the changes in the interdependency of sectors in China using five Chinese IO tables. Previous studies pertaining to the Chinese economy, and for earlier years, have relied on a single method (Bhalla and MA, 1990; Heimler, 1991; Sun, 1998).

Starting with a summary of earlier methods, we will provide a revised measure of linkages and apply it to the case of the Chinese economy. In section 2, various linkage methods will be reviewed briefly, together with their merits, limits and refinements by later writers. These methods are those of Chenery and Watanabe, Rasmussen, and we include also the hypothesis extraction method. Section 3 applies the linkage methods to the case of the Chinese economy, and provides an analysis of the results. In section 4, some conclusive avenues will finally be proffered.

2 Methodology

The methods dealing with intersectoral linkage measures may be summarised by two main categories. One refers to a traditional measurement based on the input (or output) coefficients. Another is the hypothesis extraction method.

2.1 Traditional Methods

Chenery-Watanabe Method

In the field of linkage analysis, the most common method is based on both the Leontief demand-driven model for which the basic formula is known as: $\boldsymbol{x} = \boldsymbol{A}\,\boldsymbol{x} + \boldsymbol{y}$, and the supply-driven model for which the basic equation is as: $\boldsymbol{x'} = \boldsymbol{x'}\boldsymbol{B} + \boldsymbol{v}$. On the basis of the two models, the first attempts to supply quantitative evaluation of backward linkage and forward linkage were made by Chenery and Watanabe (1958) in their studies on the international comparison of productive structures. They suggest using the column sums of the input coefficient matrix $\boldsymbol{A}$ as measures of backward linkages. The strength of the backward linkages of a sector j is defined as:

$$BL_j^C = \sum_{i=1}^{n} \frac{x_{ij}}{x_j} = \sum_{i=1}^{n} a_{ij} \qquad (1)$$

Where BL_j^C denotes the backward linkage of sector j for the Chenery-Watanabe method, x_{ij} is the magnitude of sector i's output used as production input by sector j, x_j is the output of sector j, and a_{ij} is the input coefficient of sector j to sector i.

Similarly, the strength of the forward linkage of sector i may be defined as:

$$FL_i^C = \sum_{j=1}^{n} \frac{x_{ij}}{x_i} = \sum_{j=1}^{n} b_{ij} \qquad (2)$$

Where FL_i^C denotes the forward linkage of sector *i*, b_{ij} is the output coefficient of sector *i* to sector *j*.

Using the two indicators, *i.e.* total intermediate input coefficients and total intermediate requirement coefficients, Chenery and Watanabe compared the structure of production for four countries (the United States, Japan, Norway, and Italy). In order to remove a major source of inter-country variation in coefficients in the original Leontief system, they take the gross domestic output as the denominator in computing input coefficients.

The Chenery-Watanabe method, based on direct input (or output) coefficients, measures only the first round of effects generated by the inter-relationships between sectors. So, these indices can also be called direct backward and forward linkages. Although this method has been used until recently, it has gradually been set aside, mainly because of its neglect of indirect effects.

Rasmussen Method

Rasmussen (1956) proposed to use the column (or row) sums of the Leontief inverse, $(\boldsymbol{I} - \boldsymbol{A})^{-1}$, to measure intersectoral linkages. The backward linkage, based on the Leontief inverse matrix, is simply defined as the column sums of the inverse matrix, *i.e.*,

$$BL_j^R = \sum_{i=1}^{n} g_{ij} \qquad (3)$$

where g_{ij} is the ijth element of Leontief inverse matrix that is denoted by $\boldsymbol{G}$, *i.e.*, $\boldsymbol{G} = (\boldsymbol{I} - \boldsymbol{A})^{-1}$. Sector j's backward linkage, BL_j^R, reflects the effects of an increase in final demand of sector *j* on overall output; in other words, it measures the extent to which a unit change in the demand for the product of sector *j* causes production increases in all sectors.

Similarly, the corresponding forward linkage can be defined by reference to the rows of the Leontief inverse matrix. Thus a measure of forward linkage of sector *i* is as:

$$FL_i^R = \sum_{j=1}^{n} g_{ij} \qquad (4)$$

It measures the magnitude of output increase in sector *i*, if the final demand in each sector were to increase by one unit; in other words, it measures the extent to which sector *i* is affected by an expansion of one unit in all sectors.

An essential empirical study in the field of input-output linkage analysis was proposed by Hirschman (1958), who used the Rasmussen linkage indicators to identify key sectors in an economy, and to study development strategies.

Several writers have criticised the use of Chenery-Watanabe's and Rasmussen's indicators insofar as they are employed in the identification of a "key" industry, or in general to determine appropriate investment patterns. Jones (1976) summarised the measures of intersectoral linkages. He found that the measure introduced by Chenery and Watanabe, which is used in Hirschman's studies, "has three deficiencies: double counting of causal linkages, neglect of indirect impact, and failure to distinguish domestic effects from operating on foreign economies" (Jones, 1976, P324). For the first problem, He pointed out that "in an input-output framework, sales of industry A to industry B are recorded as A's forward linkage and B's backward linkage, but only one of these can be effective in a causal sense" (Jones, 1976, P324).

It seems that Rasmussen's measures have overcome the neglect of indirect linkage. Unfortunately, Jones argued, it "measures direct plus indirect effects on supplier industries, but not on user industries: *i.e.*, backward but not forward linkages". In relation to Rasmussen's forward linkage (equation (4)), "it is not very enlightening to ask what happens to an industry if all industry, large or small, are to expand by identical unit increments in final demand", Jones argued (Jones, 1976, P326). Thus, Rasmussen's measures of forward linkage (the row sum of the Leontief inverse) do not provide a measure of forward linkages symmetrical to that provided by the column sum for backward linkages.

Jones suggests using the row sum of the output inverse matrix derived from the output coefficient matrix (*i.e.*, intermediate sales as share of total sales including final demand) to measure total forward linkages. This concept of forward linkage based on an output inverse matrix was introduced earlier by Augustinovics (1970). As a method of structural analysis symmetrical to the input coefficient system, the calculation avoids the double counting of causal linkages, which occurs in the previous (Chenery-Watanabe's and Rasmussen's) measures.

Formally, the supply-driven model may be expressed as:

$$\boldsymbol{x'} = \boldsymbol{x'B} + \boldsymbol{v} \qquad (5)$$

where $\boldsymbol{B}$ and $\boldsymbol{v}$ denote the output coefficient matrix and the primary input row vector, respectively. Thus, the solution of the equation can be obtained as follows:

$$\boldsymbol{x'} = \boldsymbol{v}\,(\boldsymbol{I} - \boldsymbol{B})^{-1} \quad \text{or} \quad \boldsymbol{x'} = \boldsymbol{v}\,\boldsymbol{Z} \qquad (6)$$

Where $\boldsymbol{Z} = (\boldsymbol{I} - \boldsymbol{B})^{-1}$. So forward linkages based on the output coefficient matrix can be written as:

$$FL_i^O = \sum_{j=1}^{n} z_{ij} \qquad (7)$$

where z_{ij} is the ijth element of matrix $\mathbf{Z}$, FL_i^O denotes the forward linkage of sector i; it measures the extent to which a unit change in the primary input of sector i causes production increases in all sectors.

2.2 Hypothesis Extraction Method

Original Extraction Method

The basic idea of the hypothesis extraction method, given by Strassert (1968), is to extract a sector hypothetically from an economic system, and then to examine the influence of this hypothetical extraction on other sectors of the economy. Starting with the basic balance equation of Leontief's model: $\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\,\boldsymbol{y}$, it may be assumed that one sector is extracted from the economy. Extraction of the kth sector, for example, simply means that the kth row and column of the input matrix $\boldsymbol{A}$ are deleted (not replaced by zero). Thus the equation can be rewritten as:

$$\tilde{\boldsymbol{x}}(k) = [\boldsymbol{I} - \tilde{\boldsymbol{A}}(\mathrm{k})]^{-1}\,\tilde{\boldsymbol{y}}(k) \qquad (8)$$

Where $\tilde{\boldsymbol{A}}(k)$ is a (*n-1*) x (*n-1*) input matrix by deleting *k*th sector from $\boldsymbol{A}$; $\tilde{\boldsymbol{x}}(k)$ and $\tilde{\boldsymbol{y}}(k)$ are (*n-1*) dimensions vectors corresponding to output vector $\boldsymbol{x}$ and final demand vector $\boldsymbol{y}$, respectively.

If, given $\boldsymbol{y}$ and $\tilde{\boldsymbol{y}}(k)$, the results $\tilde{\boldsymbol{x}}(k)$ should be less than $\boldsymbol{x}$, *i.e.*,

$$\tilde{x}_i(k) < x_i \quad \text{for } i = 1,2,\ldots,k-1,k+1,\ldots n. \tag{9}$$

Then, the sum of the differential between the output vector $\boldsymbol{x}$ excluding *k*th element and $\tilde{\boldsymbol{x}}(k)$ may measure the linkage effect of the extracted sector *k* on total output, *i.e.*,

$$L(k) = \sum_{i=1, i \neq k}^{n} [x_i - \tilde{x}_i(k)] \tag{10}$$

where *L(k)* denotes the linkage indicator of sector *k*. Obviously, there are two shortcomings in the above original extraction method. First, it can not distinguish the total linkages into backward and forward linkages (Cella, 1984). Second, the hypothesis of simply scrapping an entire sector from the economy seems to be rather excessive (Dietzenbacher, 1997).

Cella's Measure for Extraction Method

To overcome the former drawback of the original extraction method, Cella (1984) presented an improvement on the original extraction method. Instead of starting with backward or forward linkage, first of all, he decomposed the technological coefficient matrix and defined a total linkage effect of each sector, and then identified its two components, *i.e.*, backward linkage and forward linkage. All sectors of an economy can be divided into two groups: group one consists of the sectors that are to be extracted from the economy, briefly called sector 1 thereafter; group two encompasses all the other sectors of the economy, briefly called sector 2 below.

Accordingly, the basic balance equation of Leontief's model, $\boldsymbol{x} = \boldsymbol{A}\,\boldsymbol{x} + \boldsymbol{y}$, may be rewritten as:

$$\begin{bmatrix} \boldsymbol{x}_1 \\ \boldsymbol{x}_2 \end{bmatrix} = \begin{bmatrix} \boldsymbol{A}_{11} & \boldsymbol{A}_{12} \\ \boldsymbol{A}_{21} & \boldsymbol{A}_{22} \end{bmatrix} \begin{bmatrix} \boldsymbol{x}_1 \\ \boldsymbol{x}_2 \end{bmatrix} + \begin{bmatrix} \boldsymbol{y}_1 \\ \boldsymbol{y}_2 \end{bmatrix} \tag{11}$$

If there does not hypothetically exist any relations between the two groups of sectors, *i.e.*, if sector 1 does not sell or buy any intermediate products to or from sector 2 ($\boldsymbol{A}_{12}$ and $\boldsymbol{A}_{21}$ are equal to zero), then the above equation can be rewritten as:

$$\begin{bmatrix} \bar{\boldsymbol{x}}_1 \\ \bar{\boldsymbol{x}}_2 \end{bmatrix} = \begin{bmatrix} \boldsymbol{A}_{11} & 0 \\ 0 & \boldsymbol{A}_{22} \end{bmatrix} \begin{bmatrix} \bar{\boldsymbol{x}}_1 \\ \bar{\boldsymbol{x}}_2 \end{bmatrix} + \begin{bmatrix} \boldsymbol{y}_1 \\ \boldsymbol{y}_2 \end{bmatrix} \tag{12}$$

where $\bar{\boldsymbol{x}}_1$ and $\bar{\boldsymbol{x}}_2$ are the output vectors of sector 1 and 2 after extracting, respectively. Accordingly, the solution equations of these extracted outputs may be obtained as:

$$\begin{bmatrix} \bar{\boldsymbol{x}}_1 \\ \bar{\boldsymbol{x}}_2 \end{bmatrix} = \begin{bmatrix} (\boldsymbol{I} - \boldsymbol{A}_{11})^{-1} & 0 \\ 0 & (\boldsymbol{I} - \boldsymbol{A}_{22})^{-1} \end{bmatrix} \begin{bmatrix} \boldsymbol{y}_1 \\ \boldsymbol{y}_2 \end{bmatrix} \tag{13}$$

Thus the total linkage effect (denoted by *TL*) can be defined as:

$$TL = \boldsymbol{e}'(\boldsymbol{x} - \bar{\boldsymbol{x}}) \tag{14}$$

where $\bar{\boldsymbol{x}}$ denotes the output column vector of all sectors after extracting sector 1, $\boldsymbol{e}$ is a column summation vector (that is $e_i = 1$ for all i). In order to obtain the decomposition of total linkage into backward linkage and forward linkage, the balance equation (11) may be solved directly. The solution is expressed as:

$$\begin{bmatrix} \boldsymbol{x}_1 \\ \boldsymbol{x}_2 \end{bmatrix} = \begin{bmatrix} \boldsymbol{H} & \boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22} \\ \boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H} & \boldsymbol{G}_{22}(\boldsymbol{I} + \boldsymbol{A}_{21}\boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22}) \end{bmatrix} \begin{bmatrix} \boldsymbol{y}_1 \\ \boldsymbol{y}_2 \end{bmatrix} \tag{15}$$

where $\boldsymbol{H} = (\boldsymbol{I} - \boldsymbol{A}_{11} - \boldsymbol{A}_{12}\boldsymbol{G}_{22}\boldsymbol{A}_{21})^{-1}$, $\boldsymbol{G}_{22}=(\boldsymbol{I} - \boldsymbol{A}_{22})^{-1}$

Subtracting equation (13) from equation (15), the difference between the two results $\mathbf{x}$ and $\bar{\boldsymbol{x}}$, may thus be obtained as:

$$\begin{bmatrix} \boldsymbol{x}_1 - \bar{\boldsymbol{x}}_1 \\ \boldsymbol{x}_2 - \bar{\boldsymbol{x}}_2 \end{bmatrix} = \begin{bmatrix} \boldsymbol{H} - \boldsymbol{G}_{11} & \boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22} \\ \boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H} & \boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22} \end{bmatrix} \begin{bmatrix} \boldsymbol{y}_1 \\ \boldsymbol{y}_2 \end{bmatrix} \tag{16}$$

Where $\boldsymbol{G}_{11}=(\boldsymbol{I} - \boldsymbol{A}_{11})^{-1}$. According to equation (14), the total linkage can be decomposed as:

$$TL = \boldsymbol{e}'(\boldsymbol{x} - \bar{\boldsymbol{x}}) = [\boldsymbol{e}_1'(\boldsymbol{H} - \boldsymbol{G}_{11}) + \boldsymbol{e}_2'\boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H}]\boldsymbol{y}_1 + [\boldsymbol{e}_1'\boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22} + \boldsymbol{e}_2'\boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22}]\boldsymbol{y}_2 \tag{17}$$

Where $\boldsymbol{e}_1$ and $\boldsymbol{e}_2$ are column summation vectors for sector 1 and sector 2, respectively. Cella (1984) defined the first term in the right hand side of equation (17) as backward linkage (*BL*), the second term as forward linkage (*FL*) of sector 1, *i.e.*,

$$BL = [\boldsymbol{e}_1' (\boldsymbol{H} - \boldsymbol{G}_{11}) + \boldsymbol{e}_2'\boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H}]\, \boldsymbol{y}_1 \tag{18}$$

$$FL = [\boldsymbol{e}_1'\boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22} + \boldsymbol{e}_2' \boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22}]\, \boldsymbol{y}_2 \tag{19}$$

$$TL = BL + FL \tag{20}$$

The characteristic of Cella's method is that it excludes purely internal transaction ($\boldsymbol{G}_{11}\boldsymbol{y}_1$ and $\boldsymbol{G}_{22}\boldsymbol{y}_2$), and it is based on a consistent input-output model of the economy with a fixed set of technical coefficients. Since Cella's method is based on the decomposition of the total output of all sectors, the backward and forward linkages obtained are not symmetrical, and they are not comparable to the corresponding linkage indicators given by Chenery-Watanabe and Rasmussen.

Pure-Linkage Method

On the basis of Cella's measure of inter-industry linkages, a modification was made by Sonis et al (1995) who present a concept of pure linkage in a comparative study. The basic idea is to eliminate the feedback and internal effect completely from Cella's measures. The final formula of pure linkages is defined as:

$$BL^P = \boldsymbol{e}_2'[\boldsymbol{G}_{22}\boldsymbol{A}_{21}]\, \boldsymbol{x}_1 \tag{21}$$

$$FL^P = \boldsymbol{e}_1'[\boldsymbol{A}_{12}\boldsymbol{G}_{22}]\, \boldsymbol{x}_2 \tag{22}$$

Where BL^P, FL^P denote pure backward linkage and pure forward linkage of sector 1, respectively. According to the basic decomposition equation (15), the output of sector 1 is:

$$\boldsymbol{x}_1 = \boldsymbol{H}\,\boldsymbol{y}_1 + \boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22}\,\boldsymbol{y}_2 \qquad (23)$$

Substituting equation (23) into equation (21), we have

$$BL^P = \boldsymbol{e}_2'\,[\boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H}]\,\boldsymbol{y}_1 + \boldsymbol{e}_2'\,[\boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22}]\,\boldsymbol{y}_2 \qquad (24)$$

It is easy to note that the pure backward linkage defined by Sonis et al (1995) is actually equal to the sum of the second terms of Cella's backward and forward linkages. The meaning of pure backward linkage is clear, because the last term in the right hand side of equation (24) is the feedback of sector 2's purchases in order to produce output $\boldsymbol{G}_{22}\,\boldsymbol{y}_2$, which is to deliver final demand $\boldsymbol{y}_2$. In other words, it reflects the impact of sector 1's input coefficient on the production of sector 2. With regard to the pure forward linkage shown by equation (22), its economic meaning is not very clear, because the matrix $\boldsymbol{G}_{22}$ is an internal output multiplier matrix from final demand to output for sector 2; it seems that the product $\boldsymbol{G}_{22}\,\boldsymbol{x}_2$ does not make sense. If we replace $\boldsymbol{x}_2$ in equation (22) with

$$\boldsymbol{x}_2 = [\boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H}]\,\boldsymbol{y}_1 + [\boldsymbol{G}_{22}(\mathrm{I} + \boldsymbol{A}_{21}\boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22})]\,\boldsymbol{y}_2 \qquad (25)$$

equation (22) may be rewritten as follows:

$$FL^P = \boldsymbol{e}_1'\,[\boldsymbol{A}_{12}\boldsymbol{G}_{22}]\,[(\boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H})\,\boldsymbol{y}_1 + \boldsymbol{G}_{22}(\mathrm{I} + \boldsymbol{A}_{21}\boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22})\,\boldsymbol{y}_2] \qquad (26)$$

However, the economic meaning of every term in equation (26) is not clear. Using the data of the Brazilian input-output tables, Sonis *et al* (1995) applied Cella's measures, pure linkage measures and Rasmussen's method to the case of Brazil. The results obtained show that the values of the most of pure forward linkage indices are obviously greater than that of Cella's linkage indices.

Therefore, the pure forward linkage method of Sonis *et al* is far away from the definition of forward linkage given by Rasmussen. An alternative for pure forward linkage is to use an output coefficient matrix to measure the pure forward linkage in lieu of an input coefficient matrix. According to Cella's decomposition technique, the basic supply-driven model equation $\boldsymbol{x}' = \boldsymbol{x}' \boldsymbol{B} + \boldsymbol{v}$, can be expressed as:

$$\begin{bmatrix} \boldsymbol{x}_1' & \boldsymbol{x}_2' \end{bmatrix} = \begin{bmatrix} \boldsymbol{v}_1 & \boldsymbol{v}_2 \end{bmatrix} \begin{bmatrix} \widehat{\boldsymbol{H}} & \widehat{\boldsymbol{H}}\boldsymbol{B}_{12}\boldsymbol{Z}_{22} \\ \boldsymbol{Z}_{22}\boldsymbol{B}_{21}\widehat{\boldsymbol{H}} & \boldsymbol{Z}_{22}(\boldsymbol{I} + \boldsymbol{B}_{21}\widehat{\boldsymbol{H}}\boldsymbol{B}_{12}\boldsymbol{Z}_{22}) \end{bmatrix} \qquad (27)$$

Where $\widehat{\boldsymbol{H}} = (\boldsymbol{I} - \boldsymbol{B}_{11} - \boldsymbol{B}_{12}\boldsymbol{Z}_{22}\boldsymbol{B}_{21})^{-1}$, $\boldsymbol{Z}_{22}=(\boldsymbol{I} - \boldsymbol{B}_{22})^{-1}$

It is assumed that sector 1 does not sell any products to sector 2, *i.e.*, $\boldsymbol{B}_{12} = 0$. Similarly, the pure forward linkage based on the output coefficient matrix can be obtained as:

$$FL^P = [\boldsymbol{v}_1 \widehat{\boldsymbol{H}} \boldsymbol{B}_{12}\boldsymbol{Z}_{22} \boldsymbol{e}_1 + \boldsymbol{v}_2 \boldsymbol{Z}_{22}\boldsymbol{B}_{21} \widehat{\boldsymbol{H}} \boldsymbol{B}_{12}\boldsymbol{Z}_{22} \boldsymbol{e}_2] \qquad (28)$$

The Dietzenbacher & van der Linden Method

As mentioned above, one of the drawbacks existing in the original extraction method is that it does not split total linkages into backward and forward linkages. A revised extraction method was presented by Dietzenbacher and van der Linden (1997), who measure the backward and forward linkages separately by using a non-complete extraction method.

Basically, the revised extraction method is similar to the decomposition technique proposed by Cella. Starting from the decomposition equation (11), it is assumed in the case of backward linkages, that all the elements of column j of the input coefficient matrix are equal to zero, *i.e.*, $\boldsymbol{A}_{jj} = 0$, $\boldsymbol{A}_{rj} = 0$, ($\boldsymbol{A}_{jj}$ denotes the input coefficient of sector j to itself; $\boldsymbol{A}_{rj}$ denotes the input coefficient vector of sector j to the other sectors). In other words, sector j buys no intermediate inputs from any production sectors. Mathematically, the extracted model can be expressed as:

$$\widehat{\boldsymbol{x}}(j) = \begin{bmatrix} \widehat{\boldsymbol{x}}_j \\ \widehat{\boldsymbol{x}}_r \end{bmatrix} = \begin{bmatrix} 0 & \boldsymbol{A}_{jr} \\ 0 & \boldsymbol{A}_{rr} \end{bmatrix} \begin{bmatrix} \widehat{\boldsymbol{x}}_j \\ \widehat{\boldsymbol{x}}_r \end{bmatrix} + \begin{bmatrix} \boldsymbol{y}_j \\ \boldsymbol{y}_r \end{bmatrix} \qquad (29)$$

Where $\hat{\boldsymbol{x}}_j$, $\hat{\boldsymbol{x}}_r$ denote sector j's output and the output vector of the remaining sectors, respectively; $\hat{\boldsymbol{x}}(j)$ denotes the total output vector after extracting sector j; $\boldsymbol{y}_j$, $\boldsymbol{y}_r$ are the final demand vectors of sector j and of the remaining sectors, respectively. Similarly, the solution for the extracted output $\hat{\boldsymbol{x}}(j)$ can be obtained as:

$$\hat{\boldsymbol{x}}(j) = \begin{bmatrix} \hat{\boldsymbol{x}}_j \\ \hat{\boldsymbol{x}}_r \end{bmatrix} = \begin{bmatrix} \boldsymbol{I} & \boldsymbol{A}_{jr}\boldsymbol{G}_{rr} \\ 0 & \boldsymbol{G}_{rr} \end{bmatrix} \begin{bmatrix} \boldsymbol{y}_j \\ \boldsymbol{y}_r \end{bmatrix} \tag{30}$$

Thus, the total absolute backward linkage of sector j is defined as:

$$d(j) = \boldsymbol{e}' \, [\boldsymbol{x} - \hat{\boldsymbol{x}}(j)\,] \tag{31}$$

$$d(j) = \boldsymbol{e}' \begin{bmatrix} \boldsymbol{H} - \boldsymbol{I} & (\boldsymbol{H} - \boldsymbol{I})\boldsymbol{A}_{jr}\boldsymbol{G}_{rr} \\ \boldsymbol{G}_{rr}\boldsymbol{A}_{rj}\boldsymbol{H} & \boldsymbol{G}_{rr}\boldsymbol{A}_{rj}\boldsymbol{H}\boldsymbol{A}_{jr}\boldsymbol{G}_{rr} \end{bmatrix} \begin{bmatrix} \boldsymbol{y}_j \\ \boldsymbol{y}_r \end{bmatrix} \tag{32}$$

$$d(j) = [(\boldsymbol{H}\text{-}\boldsymbol{I}) + \boldsymbol{e}_r' \boldsymbol{G}_{rr}\boldsymbol{A}_{rj}\boldsymbol{H}]\, \boldsymbol{y}_j + [(\boldsymbol{H}\text{-}\boldsymbol{I})\boldsymbol{A}_{jr}\boldsymbol{G}_{rr} + \boldsymbol{e}_r' \boldsymbol{G}_{rr}\boldsymbol{A}_{rj}\boldsymbol{H}\boldsymbol{A}_{jr}\boldsymbol{G}rr]\, \boldsymbol{y}_r \tag{33}$$

The magnitude of the absolute backward linkage *d(j)* is determined by a combination of two factors: the size of sector j and its output multipliers. Since the primary concern of linkage analysis is the structure of production, the size effect of sectors should be eliminated in the linkage measurements. To this end, the result *d(j)* is normalised by dividing the absolute figures by the value of sector j's output. This yields the backward linkage of sector j as:

$$BL_j^D = \frac{d(j)}{x_j} \times 100 \tag{34}$$

Starting with the supply-driven model $\boldsymbol{x}' = \boldsymbol{x}'\boldsymbol{B} + \boldsymbol{v}$, the corresponding forward linkage indicators can be obtained similarly by using the extraction technique. For the supply-driven system, it is assumed that sector j sells no output to any of the production sectors. Row i in the output coefficient matrix $\boldsymbol{B}$ is set at zero. The corresponding output $\breve{\boldsymbol{x}}'(\mathrm{i})$ can be obtained as:

$$\breve{\boldsymbol{x}}'(i) = \begin{bmatrix} \breve{\boldsymbol{x}}_i & \breve{\boldsymbol{x}}'_r \end{bmatrix} = \begin{bmatrix} \boldsymbol{v}_i & \boldsymbol{v}_r \end{bmatrix} \begin{bmatrix} \boldsymbol{I} & 0 \\ \boldsymbol{Z}_{rr}\boldsymbol{B}_{ri} & \boldsymbol{G}_{rr} \end{bmatrix} \quad (35)$$

The difference between $\boldsymbol{x}$ and $\breve{\boldsymbol{x}}(\mathrm{i})$ is defined as the absolute forward linkage, i.e.

$$d^*(i) = [\boldsymbol{x}' - \breve{\boldsymbol{x}}'(\mathrm{i})]\,\boldsymbol{e} \quad (36)$$

$$d^*(i) = \begin{bmatrix} \boldsymbol{v}_i & \boldsymbol{v}_r \end{bmatrix} \begin{bmatrix} \widehat{\boldsymbol{H}} - \boldsymbol{I} & \widehat{\boldsymbol{H}}\boldsymbol{B}_{ir}\boldsymbol{Z}_{rr} \\ \boldsymbol{Z}_{rr}\boldsymbol{B}_{ri}(\widehat{\boldsymbol{H}} - \boldsymbol{I}) & \boldsymbol{Z}_{rr}\boldsymbol{B}_{ri}\widehat{\boldsymbol{H}}\boldsymbol{B}_{ir}\boldsymbol{Z}_{rr} \end{bmatrix} \boldsymbol{e} \quad (37)$$

$$d^*(i) = \boldsymbol{v}_i\,[(\widehat{\boldsymbol{H}} - \boldsymbol{I}) + \widehat{\boldsymbol{H}}\,\boldsymbol{B}_{ir}\boldsymbol{Z}_{rr}\,\boldsymbol{e}_r] + \boldsymbol{v}_r[\boldsymbol{Z}_{rr}\boldsymbol{B}_{ri}(\widehat{\boldsymbol{H}} - \boldsymbol{I}) + \boldsymbol{Z}_{rr}\boldsymbol{B}_{ri}\widehat{\boldsymbol{H}}\,\boldsymbol{B}_{ir}\boldsymbol{Z}_{rr}]\boldsymbol{e}_r \quad (38)$$

The relative forward linkage of sector j can, accordingly, be defined as

$$FL_i^D = \frac{d^*(i)}{x_i} \times 100 \quad (39)$$

2.3 Summary

The measures of backward linkages (or forward linkages) explore the effects (or impacts) of a change in final demand (or primary inputs) on the total output of sectors in different respects. Rasmussen's backward (or forward) linkage indicators measure the effects of one monetary unit change in final demand (or primary inputs) of each sector on total output of all sectors (including the sector itself). The backward (or forward) linkage indicators of the Dietzenbacher & van der Linden method examine the extent of the impact derived from the hypothetical extraction of a sector on total output, when final demand (or primary inputs) increases by one monetary unit in all sectors. This actually includes the effect of all other sectors on total output through the feedback in connection with the inputs (or sales) of the extracted sector. Differing from the Dietzenbacher and van der Linden method, the linkage indicators of the pure-linkage method measures only the effects of the sector on the output of other sectors (it excludes the effect on its own output).

The traditional methods, *i.e.*, the Chenery-Watanabe and the Rasmussen methods, concern only the effects of per unit final demand of sector 1 on total output. It is to say that the calculations do not involve the size of final demand of all sectors. This therefore allows for comparability between countries or over time within a country. The pure-linkage method and the Cella method involve not only output multipliers, but also the magnitudes of final demand of all sectors. So they raise the difficulty of having cross-country comparisons or comparisons over time within a country.

We chose and apply four methods to the case of the Chinese economy in this paper. These are the Chenery-Watanabe method, the Rasmussen method, the pure-linkage method, and the Dietzenbacher and van der Linden method. The reasons of so doing are twofold: first, to examine the characteristics of intersectoral interdependence in production processes; second, to compare the differences between the four methods using empirical data. In order to make the four methods comparable over time and to allow for some comparison between methods, an attempt at revising the pure-linkage method has to be made. As mentioned above, the pure-linkage method is not independent of the unit of measurement (*i.e.*, the value of the linkage indicators depend upon the size of final demand). An alternative is to use the share of each sector in final demand (or primary inputs) to replace the absolute value of final demand (or primary inputs). Hence, the revised pure-linkage indices reflect the effects of a sector on the output of other sectors when final demand (or primary inputs) increases by one unit. The four methods used in the study are summarised in the following table.

	Backward linkage	Forward linkage
Chenery-Watanabe	$BL_j^C = \sum_{i=1}^{n} a_{ij}$	$FL_i^C = \sum_{j=1}^{n} b_{ij}$
Rasmussen	$BL_j^R = \sum_{i=1}^{n} g_{ij}$	$FL_i^O = \sum_{j=1}^{n} z_{ij}$
Pure-linkage	$BL_j^P = \boldsymbol{e}_r' [\boldsymbol{G}_{rr}\boldsymbol{A}_{rj}\boldsymbol{H}] + \boldsymbol{e}_r' [\boldsymbol{G}_{22}\boldsymbol{A}_{21}\boldsymbol{H}\boldsymbol{A}_{12}\boldsymbol{G}_{22}]\, \boldsymbol{y}_r$	$FL_i^P = [\, \widehat{\boldsymbol{H}}\, \boldsymbol{B}_{ir}\boldsymbol{Z}_{rr}\,]\boldsymbol{e}_r + \boldsymbol{v}_r\, [\boldsymbol{Z}_{rr}\boldsymbol{B}_{ri}\, \widehat{\boldsymbol{H}}\, \boldsymbol{B}_{ir}\boldsymbol{Z}_{rr}]\, \boldsymbol{e}_r$
Dietzenbacher	$BL_j^D = [(\boldsymbol{H}\text{-}\boldsymbol{I}) + \boldsymbol{e}_r'\, \boldsymbol{G}_{rr}\boldsymbol{A}_{rj}\boldsymbol{H}]\, /x_j + [(\boldsymbol{H}\text{-}\boldsymbol{I})\boldsymbol{A}_{jr}\boldsymbol{G}_{rr} + \boldsymbol{e}_r'\, \boldsymbol{G}_{rr}\boldsymbol{A}_{rj}\boldsymbol{H}\boldsymbol{A}_{jr}\boldsymbol{G}_{rr}]\boldsymbol{e}r\, /x_j$	$FL_i^D = [(\, \widehat{\boldsymbol{H}}\ \text{-}\boldsymbol{I}) + \widehat{\boldsymbol{H}}\, \boldsymbol{B}_{ir}\boldsymbol{Z}_{rr}\boldsymbol{e}_r]/x_i + \boldsymbol{e}_r'\, [\boldsymbol{Z}_{rr}\boldsymbol{B}_{ri}(\, \widehat{\boldsymbol{H}}\ \text{-}\boldsymbol{I}) + \boldsymbol{Z}_{rr}\boldsymbol{B}_{ri}\, \widehat{\boldsymbol{H}}\, \boldsymbol{B}_{ir}\boldsymbol{Z}_{rr}\boldsymbol{e}_r]/x_i$

The common characteristic of the four chosen methods is that their backward linkages and forward linkages all are symmetric. The backward linkages are all based on the same demand-driven model, and the forward linkage on the same supply-driven model.

Index of overall intersectoral interdependence

The various measures of intersectoral linkages discussed above measure the extent of intersectoral interdependence for individual sectors. Through these linkage indicators, we may disclose the change in the interdependence of individual sectors and the extent of intersectoral interconnections. Moreover, what happened in the overall interdependence of the economy considered as a whole? Would the overall degree of intersectoral interdependence change over time with the change in production structure? These questions should be answered by the linkage analysis. It is imperative, therefore, to propose an index of overall interdependence to measure the extent of change in intersectoral interdependence as a whole. For the Chenery-Watanabe method and the Rasmussen method, a feasible scheme is to weight the backward linkage indicators (or forward linkage indicators) by using the share of sectors in final demand (or primary inputs). The basic idea of a weighting average was proposed by Laumas (1976). Considering the relative importance of each sector in terms of final demand or primary inputs, indices of overall intersectoral interdependence are defined as:

$$TOL = \sum_{i=1}^{n} \alpha_j BL_j \tag{40}$$

or

$$TOL = \sum_{i=1}^{n} \beta_i FL_i \tag{41}$$

Where TOL are the index of overall intersectoral interdependence for the Chenery-Watanabe method and the Rasmussen method; α_j is the share of sector j in final demand, β_i is the share of sector i in primary inputs. Khayum (1995) uses this type of indicator to examine the overall intersectoral interdependence in the United States. He argued that "this indicator measures the combined effect of all sectoral linkages that is attributable to an exogenous change in a unit's worth of output or value-added. It also allows for a proper comparison of the overall backward or forward stimulus experienced by an economy over time since the backward and forward linkage indexes are weighted according to the relative importance of each sector in the economy" (Khayum, 1995, p35).

For the Dietzenbacher and van der Linden method, the indices of overall interdependence may be defined as:

$$BOL = \frac{1}{n}\sum_{j=1}^{n}\frac{BL_j x_j}{\sum_j x_j} \tag{42}$$

$$FOL = \frac{1}{n}\sum_{i=1}^{n}\frac{FL_i x_i}{\sum_i x_i} \tag{43}$$

Where *BOL*, *FOL* are the indices of overall intersectoral interdependence of backward linkage and forward linkage, respectively, for the Dietzenbacher and van der Linden method.

For the pure-linkage method, the indices of overall interdependence can be defined as:

$$BOL = \frac{1}{n}\sum_{j=1}^{n}\frac{BL_j Y}{\sum_j x_j} \tag{44}$$

$$FOL = \frac{1}{n}\sum_{i=1}^{n}\frac{FL_i V}{\sum_i x_i} \tag{45}$$

Where *Y* and *V* are total final demand and total primary inputs, respectively. These indices of overall interdependence for the Dietzenbacher and the pure-linkage methods denote the averages of the ratios of the intermediate requirements caused by intersectoral linkages to total output. Therefore, they reflect the extent of intersectoral interdependence as a whole.

3 Application: Intersectoral Linkages and Key Sectors in China

The various measures of linkages discussed above have been computed for the Chinese 1987, 1990, 1992, 1995, and 1997 IO tables. First of all, to examine intersectoral interdependence in the main sector categories, these tables need to be aggregated into 5-sector tables respectively, which consist of Agriculture, Mining, Manufacturing, Construction, and Services.

3.1 General Tendency in Intersectoral Linkages

Taking the entire data sets of five input-output tables in the 5 aggregated sectors, a series of the four methods previously discussed, were implemented. The results derived from the four methods are presented in Tables 1 and 2.

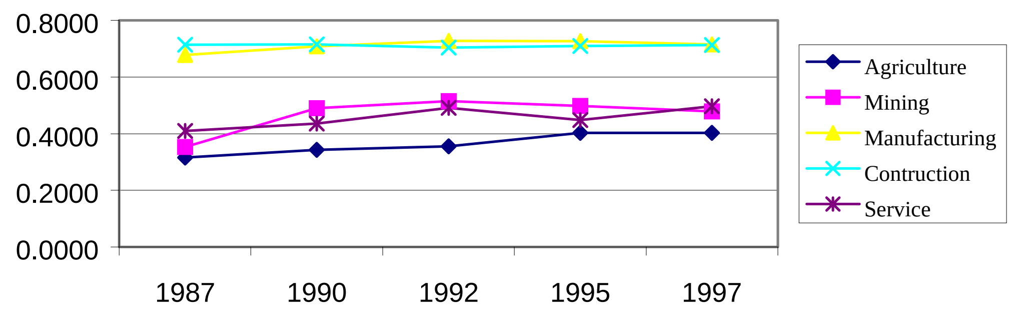
Table 1 Backward linkages resulting from the various methods

	1987	1990	1992	1995	1997
Chenery & Watanabe					
Agriculture	0.3152	0.3429	0.3558	0.4023	0.4026
Mining	0.3526	0.4899	0.5145	0.4979	0.4786
Manufacturing	0.6777	0.7089	0.7271	0.7268	0.7147
Construction	0.7139	0.7147	0.7041	0.7096	0.7125
Services	0.4096	0.4359	0.4915	0.4486	0.4969
Average	0.4938	0.5385	0.5586	0.5570	0.5611
Rasmussen					
Agriculture	1.6463	1.7388	1.8535	1.9757	1.9946
Mining	1.8343	2.2622	2.3991	2.3524	2.2780
Manufacturing	2.5422	2.7621	2.9320	2.9658	2.9247
Construction	2.7333	2.8937	2.9577	2.9839	2.9890
Services	1.9268	2.0738	2.2926	2.1731	2.3182
Average	2.1366	2.3461	2.4870	2.4902	2.5009
Dietzenbachar & vdL					
Agriculture	0.4396	0.4823	0.6241	0.6778	0.7102
Mining	0.7917	1.1794	1.2632	1.2271	1.1269
Manufacturing	0.7804	0.8325	0.8802	0.8556	0.8502
Construction	1.7333	1.8937	1.9346	1.9584	1.9711
Services	0.7537	0.8641	0.9301	0.8939	0.9825
Average	0.8997	1.0504	1.1264	1.1226	1.1282
Pure linkage					
Agriculture	0.1451	0.1617	0.1821	0.1932	0.1954
Mining	0.0547	0.0938	0.0965	0.1041	0.0961
Manufacturing	0.3251	0.3847	0.4412	0.4230	0.4170
Construction	0.3688	0.3287	0.3755	0.4386	0.4506
Services	0.2354	0.2872	0.4136	0.3410	0.4080
Average	0.2258	0.2512	0.3018	0.3000	0.3134

Backward Linkages

It is shown in the first block of Table 1 that the magnitude of direct backward linkages increased gradually for Agriculture. In general, the services sector also experienced a trend of increase in terms of the values of direct backward linkage, with the exception of a slight decline in 1995. This indicator increased firstly in 1990 and 1992, and then decreased in 1995 and 1997 for Mining and Manufacturing, while remaining fairly stable for Construction. Since the direct backward linkage indicator represents the ratio of intermediate to total output for each sector, it illustrates an increased reliance on intermediate inputs in agriculture and in the services sectors. This tendency may be clearly seen in Figure 1.

Figure 1 Direct backward linkages (Chenery-Watanabe)



The trends of backward linkages according to the Rasmussen method, the Dietzenbacher and van der Linden method and the pure-linkage method are quite similar to that of the direct backward linkage for Agriculture and Services. Deviations in behaviour between the Chenery-Watanabe measures and other three measures of backward linkages occur in Construction, which show an increase rather than stability in the values of the other three measurements of backward linkage during the period of time 1987 and 1997. The difference also appeared in Manufacturing for which the values of the Rasmussen method experienced an increasing trend. This is to say that the total effects (direct plus indirect effects) of manufacturing sectors on total output have been rising though the direct effects remained relatively stable. For Mining, the values of the pure-linkage and the Dietzenbacher and van der Linden methods differ from that of the Chenery-Watanabe and the Rasmussen methods. With the exception of a slight decrease in 1997, basically the values of the relative and pure backward linkages in Mining increased during the period of time reviewed (see Figures 2, 3, 4).

Figure 2 Total backward linkages (Rasmussen)

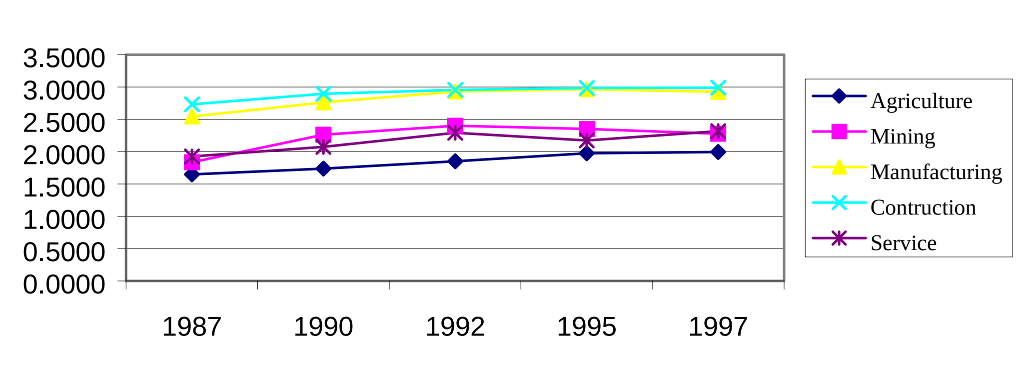


Figure 3 Relative backward linkages (Dietzenbacher and van der Linden)

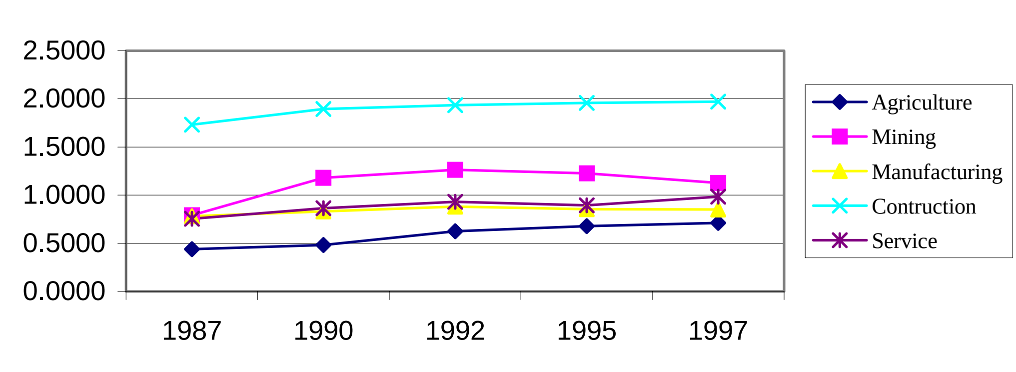


Figure 4 Pure backward linkages (Pure-linkage)

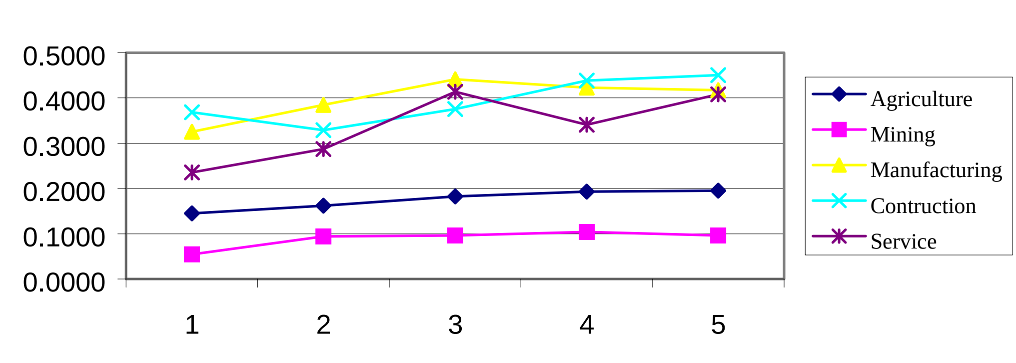


Table 1 shows that the output effects have risen over time in agriculture and service sectors according to the four methods; in Construction for three of the four measurements; in Manufacturing for the Rasmussen method; and in Mining for the last two methods. The changes in values of various backward linkages suggest that, as the economy has increasingly become manufacturing-oriented, *i.e.* the growth rate of

Manufacturing is the greatest, the degree to which the sectors are interconnected has also changed; the sectors became more interdependent one another. In addition, the results of the Rasmussen method show that indirect backward linkages of each sector obtained by deducting direct backward linkages from total backward linkages are greater than direct backward linkage. In other words, the indirect connections of sectors in an economy are in a sense much more complex and important than the direct ones.

Forward Linkages

The results of forward linkages measured by the various methods for the 5-sector tables are presented in Table 2. For the Chenery-Watanabe method, it is shown in block one of Table 2 that the values of direct forward linkage follow, by and large, an increasing trend in Agriculture, Mining, Manufacturing, and Services (see Figure 5).

Since the direct forward linkage indicator represents the ratio of intermediate demand to total output of a sector, the patterns of increasing intermediate demand suggest that one aspect of economic change between 1987 and 1997 is a relatively greater intermediate demand orientation rather than final demand orientation in sectoral output.

From Table 2, it is easy to find that the forward linkages measured by the Rasmussen method and the Dietzenbacher & van der Linden method also trace a path of increase in the case of the four sectors, Agriculture, Mining, Manufacturing, and Services. The increased trends are very similar to that of the direct forward linkage of the Chenery-Watanabe method. An upward trend in forward linkages of the pure-linkage method is detected for Mining and Manufacturing. These tendencies performed by three kinds of forward linkages are shown clearly in Figure 6 to 8.

Table 2 Forward linkages resulting from the various methods

	1987	1990	1992	1995	1997
Chenery-Watanabe					
Agriculture	0.4661	0.5375	0.4907	0.5441	0.5435
Mining	0.9167	0.9011	0.9570	0.9323	1.0396
Manufacturing	0.6996	0.6991	0.7277	0.7277	0.7407
Construction	0.0000	0.0000	0.0447	0.0371	0.0592
Services	0.4664	0.4747	0.5627	0.5677	0.5211
Average	0.5098	0.5225	0.5565	0.5618	0.5808
Rasmussen					
Agriculture	2.1149	2.3847	2.3362	2.5139	2.5223
Mining	3.1190	3.2445	3.6334	3.5663	4.0218
Manufacturing	2.5664	2.7081	2.9177	2.9423	2.9744
Construction	1.0000	1.0000	1.1030	1.0833	1.1437
Services	2.0584	2.1490	2.4721	2.4944	2.3442
Average	2.1717	2.2973	2.4925	2.5200	2.6013
Dietzenbacher & vdL					
Agriculture	0.9173	1.0904	1.1060	1.1990	1.2206
Mining	2.0110	2.0886	2.3777	2.3285	2.6647
Manufacturing	0.7926	0.8035	0.8737	0.8454	0.8722
Construction	0.0000	0.0000	0.1018	0.0822	0.1424
Service	0.8607	0.9202	1.0593	1.1387	1.0018
Average	0.9163	0.9805	1.1037	1.1188	1.1804
Pure linkage					
Agriculture	0.3029	0.3850	0.3184	0.3391	0.3333
Mining	0.1447	0.1713	0.1888	0.2052	0.2426
Manufacturing	0.3390	0.3518	0.4327	0.4081	0.4484
Construction	0.0000	0.0000	0.0176	0.0156	0.0306
Services	0.2798	0.3131	0.4959	0.4683	0.4188
Average	0.2133	0.2442	0.2906	0.2873	0.2948

Figure 5 Direct forward linkages (Chenery-Watanabe)

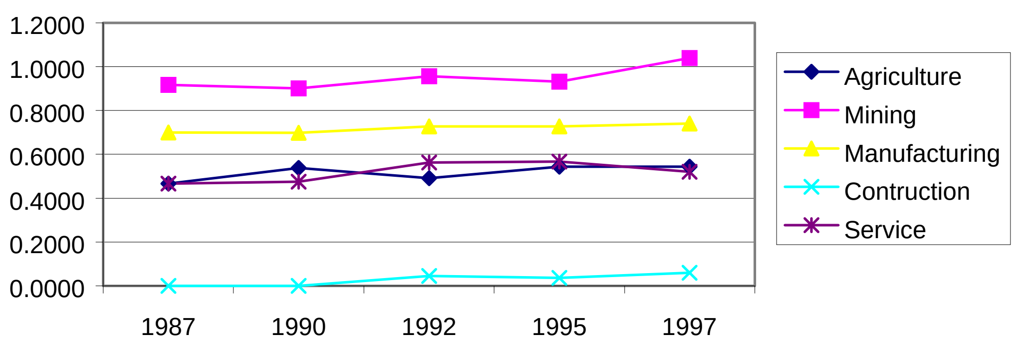


Figure 6 Total forward linkages (Rasmussen)

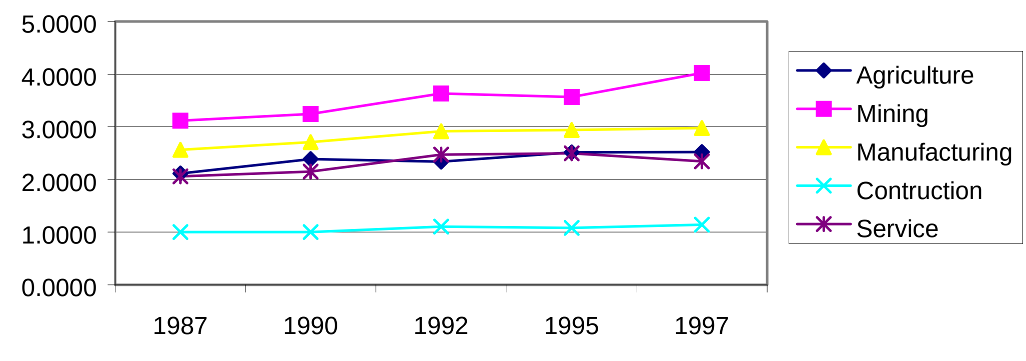


Figure 7 Relative forward linkages (Dietzenbacher and van der Linden)

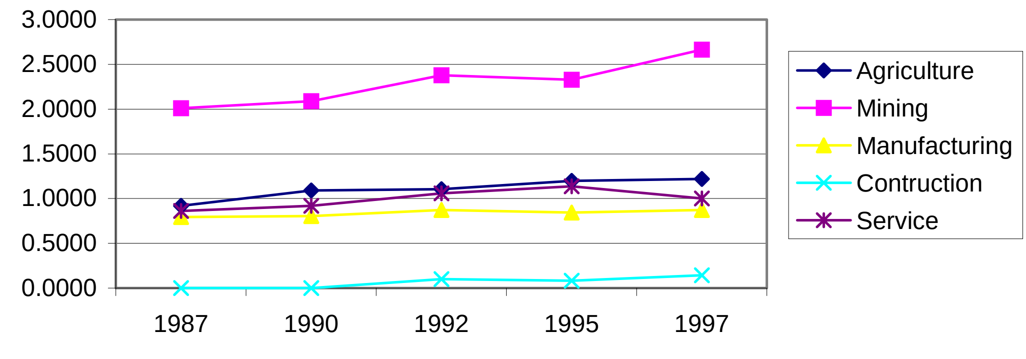
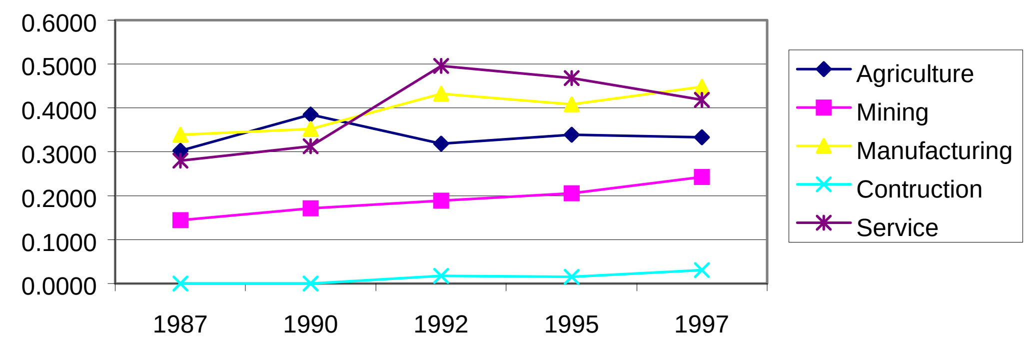


Figure 8 Pure forward linkages (Pure-linkage)



The values of backward linkages for Construction are above the average for all methods used in the study. This suggests that Construction has strong backward linkages in many respects. Except for the Dietzenbacher and van der Linden method, the values of backward linkage of Manufacturing are above average for the other three methods. This indicates that the Manufacturing sector has strong direct, total and pure backward linkages. But, its relative backward linkage is weak. In terms of the pure backward linkage, the values of Services are above average. That is to say that the impact of Services on the output of other sectors is relatively high. But it is not held in the other measurements.

The results of various measurements of forward linkages show that the values of Manufacturing are greater than the corresponding average for the Chenery-Watanabe, the Rasmussen, and the pure-linkage methods. So, Manufacturing has strong direct, total and pure forward linkages. For Mining, excepting for the pure-linkage measures, this indicator is above average for the other three methods. It is noteworthy that the values of Agriculture are greater than average in the case of the Dietzenbacher & van der Linden and the pure-linkage methods. It indicates that Agriculture has a strong interconnection with other sectors in terms of relative and pure forward linkage. In addition, the values of Services are also above average for pure forward linkages. This shows that Services played an important role in production activities during the decade reviewed. This point is not shown by other measures.

3.2 Intersectoral Interdependence for the 33 sectors

The focus of this section will be on the results derived from 33-sector tables to disclose the intersectoral linkages and interdependence for the detailed sectors and a comparison of the results derived from the four methods. For the 33-sector tables the linkage indicators of various methods have been calculated. The results are presented in Table 3 and Table 4.

Backward Linkages

Table 3 shows that the values of direct backward linkage calculated by the Chenery-Watanabe method show a gradual increase in the cases of Agriculture (1), Metal ore (4), Petroleum refining (12), Building material (15), Metal products (17), and Electrical machinery (20). There are fifteen sectors for which the backward linkages experience an increasing trend during the period of time except for a slight jump or fall in an individual year. These are Coal (2), Crude petroleum (3), Paper (10), Electricity (11), Chemicals (14), Primary metals (16), Machinery (18), Transport equipment (19), Electronics (21), Instruments (22), Freight transport (26), Passenger transport (29), Public utilities (30), and Public administration (33). This illustrates that these sectors have more and more relied on intermediate inputs over the decade considered. The number of these sectors that have experienced a basic increase in backward linkages accounts for 63.6 percent of total sectors. In addition, the values of direct backward linkages remain relatively stable for Food (6), Coking (13), Construction (25), Commerce (27), and Culture (31) sectors. There are five sectors, Other mining (5), Clothing (8), Sawmills (9), Maintenance (23) and Other manufacturing (24), for which the values of direct backward linkages increase first and then decrease during the decade.

The behaviours of backward linkages according to the Rasmussen method are basically the same as those of direct backward linkages. Some differences can be observed for Food (6), Clothing (8), Coking (13), and Construction (25); for these sectors, the total backward linkages experience an increasing trend except for a slight jump or fall in an individual year. That is to say that the indirect effect (total effect minus direct effect) of these sectors on output increased over the period of time reviewed.

The results of backward linkage derived from the Dietzenbacher measures show that the changes in the value of relative backward linkages are quite similar in trend to that of direct and total backward linkages for most sectors. A different behaviour can be noticed in Chemicals (14) and Metal products (17), for which the figure began decreasing since 1995, but this is not held for direct and total backward linkages.

The last five columns of Table 3 present the results of backward linkages of the pure-linkage method. A gradual increased trend in the value of pure backward linkages is observed in Metal ore (4), Food (6), Electricity (11), Building materials (15), Metal products (17), Transport equipment (19), Electrical machinery (20), Electronics (21). This trend does not occur in Paper (10), Chemicals (14) and Machinery (18), sectors for which there are increased trends in direct and total backward linkages.

Forward Linkages

The results of direct forward linkages are shown in Table 4. There are obvious increasing trends in terms of values of direct forward linkages for Agriculture (1), Coal (2), Crude petroleum (3), Chemicals (14), Machinery (18), Electrical machinery

(20), Electronics (21), Maintenance (23), and Freight transport (26). In addition and except for an individual year, a general decreasing trend in direct forward linkages may be observed in the case of Sawmills (9), Building materials (15), Other industries (24), and Commerce (27). This indicates that final demand grew faster than intermediate demand in the growth of these sectors' output. In other words, there are continuous shifts in output allocation of these sectors from intermediate to final demand during the decade.

For the Rasmussen method, the results show a gradual increase in total forward linkages (direct plus indirect forward linkage) for Food (6), Petroleum refining (12), Metal products (17), Machinery (18), and Maintenance (23). In addition, a basic increasing trend can be found in the cases of Coal (2), Crude petroleum (3), Other mining (5), Paper (10), Electricity (11), Chemicals (14), Primary metals (16), Electrical machinery (20), Electronics (21), Freight transport (26), and Public utilities (30). It indicates that the degree of dependence of all sectors on these sectors in production process became higher and higher over the period of time reviewed.

For the Dietzenbacher and van der Linden method, the values of relative forward linkages increased gradually in the case of Food (6), Machinery (18), and Maintenance (23). There are twelve sectors for which the relative forward linkages trace a path of increase basically except for a slight jump or fall in an individual year. These are Coal (2), Crude petroleum (3), Paper (10), Electricity (11), Petroleum refining (12), Chemicals (14), Primary metals (16), Metal products (17), Electrical machinery (20), Electronics (21), Freight transport (26), and Public utilities (30).

For the pure-linkage method, the values of pure forward linkages experienced an increasing trend in the case of Food (6), Petroleum refining (12), Metal products (17), Electrical machinery (20), Electronics (21), Instruments (22), and Maintenance (23). Except for a slight decline in an individual year, this indicator shows a general increasing trend for Coal (2), Crude petroleum (3), Metal ore (4), Other mining (5), Clothing (8), Sawmills (9), Paper (10), Electricity (11), Chemicals (14), Freight transport (26), Passenger transport (29). Of the fifteen sectors belonging to the manufacturing industry, four sectors belong to the mining industry. That is to say that these sectors played a more and more important role in the production process of China during the period of time studied.

3.3 Comparison of the results given by the four methods

Although there are similarities in the trends of change in backward linkages and forward linkages for the four methods, it is easy to find that there are obvious differences between the rankings of the linkage indicators for the four methods. For example, the backward linkage for Petroleum refining (12) ranks at position 2 in 1997 according to the Chenery-Watanabe method, but according to the Dietzenbacher and van der Linden method and to the Pure-linkage method, the position is 15 and 21 in 1997, respectively. In this subsection, using the 1997 data as a sample, we try to compare the ranking of the two linkage indicators for the four methods, in order to disclose the differences between these measures. Because the latest 1997 input-output table includes imports and exports columns separately, we may recalculate various indicators for the 1997 table using the domestic model, so as to examine the differences between the methods exactly. The results are presented in Table 5.

For the backward linkages in Table 5, remarkable differences are observed in the case of Food (6), Clothing (8), Electricity (11), Petroleum refining (12), Chemicals (14), Commerce (27), Electronics (21), etc. For the forward linkages, obvious differences may be found in the cases of Crude petroleum (3), Metal ore (4), Textile (7), Electricity (11), Chemicals (14), Coking (13), Primary metal (16), Electrical machinery (20), Electronics (21), Commerce (27), Freight transport (26), etc. Below, we will give a brief explanation for these differences, starting with the backward linkages.

Backward linkages

For Agriculture (1), the ranking given by the pure-linkage method is much higher than that produced by the other three methods; this can be attributed to the high share of the agricultural sector in final demand. It appears that the pure-linkage method overestimates the backward linkages of the agricultural sector.

In food sector (6), 72.3 percent of its total input is for intermediate consumption, so the ranking position of the Chenery-Watanabe method is relatively high. However, 42.9 percent of its intermediate inputs comes from agriculture, sector in which the value of backward linkages is very low according to the Chenery-Watanabe, the Rasmussen and the Dietzenbacher & van der Linden methods. The higher position of the pure backward linkages for the food industry can be attributed to its higher share in final demand, which is 11.45 percent. Therefore, it seems that the Chenery-Watanabe method and the pure-linkage method overestimate the backward linkages of food sector in comparison with the other two methods.

For Textiles (7), the rankings of the Chenery-Watanabe method and Rasmussen method are relatively higher. The 1997 input-output table shows that the intermediate input of the textile sector accounts for 66.1 percent, of which 34.4 percent comes from the sector itself, and 12.3 percent comes from agriculture, sector for which the value of backward linkage is very low according to both the Chenery-Watanabe and the Rasmussen methods. So, it seems that there are some overestimations of backward linkages in the case of the textile sector for the Rasmussen method and Chenery-Watanabe method.

For Sawmills (9), its intermediate inputs account for 67.77 percent of total inputs, of which 22.22 percent comes from the sector itself. It is the biggest source of its intermediate input. On the other hand, the share of the sawmills sector in final demand is very low (0.96%). Therefore, it seems that the Chenery-Watanabe method and the Rasmussen method overestimate the backward linkage of Sawmills in comparison with the pure-linkage method.

For sector (12), Petroleum refining, the ranking of backward linkages given by the Chenery-Watanabe method is obviously higher than that of obtained by the other three methods. The ratio of its intermediate inputs is 62.69 percent, of which 41.71 percent comes from the crude petroleum sector. It should be noted that Crude petroleum (3) has very low backward linkages. Therefore, it seems that the Chenery-Watanabe method overestimates the backward linkages of the petroleum refining sector.

For Coking (13), its rankings given by the four methods are very different. For the Chenery-Watanabe method, it ranks at position 1, which is due to the fact that the ratio of its intermediate input is the highest (73.02 percent). But 31.79 percent of its intermediate inputs comes from Crude petroleum (3) for which the values of backward linkages are very low. The share of the coking sector in total output is the smallest, which implies that the value of backward linkages, as reported by the Diezenbacher and van der Linden method is very high. So, it seems that the Chenery-Watanabe method and the Dietzenbacher and van der Linden method overestimate the backward linkages of the coking sector. For the pure-linkage method, its ranking position is the last one. This may be attributed to the low share of Coking in final demand. Comparing with the other methods, it appears that the pure-linkage method underestimates the backward linkage of Coking.

In sector (14), Chemicals, the values of backward linkage generated by the Chenery-Watanabe method and the Rasmussen method are comparably high. They rank at position 9 and 7, respectively. The input-output table shows that there are twenty sectors that have a higher intermediate input ratio (> 3 percent) for chemicals sector. Considering this factor, the pure-linkage method reported a higher-ranking position (5) though its share in final demand is not very high. For the same reason, the Dietzenbacher and van der Linden method should give a higher ranking also. However, its output is rather big, which accounts for 7.6 percent of total output. This induces that the relative backward linkages become lower. It ranks at position 27 only. So it appears that there are an underestimation of backward linkages derived from the Dietzenbacher and van der Linden method in the chemicals sector.

For Primary metals (16), its intermediate inputs accounts for 73 percent of total inputs, so the rankings of backward linkages given by the Chenery-Watanabe method and the Rasmussen method are very high. The input-output table shows that 35.58 percent of intermediate inputs comes from the sector itself. The share of the primary metal sector in final demand is very low. Therefore, the Chenery-Watanabe method and the Rasmussen method seem to overestimate the backward linkages of Primary metals.

For Machinery (18), its intermediate input ratio is 58.6 percent. So the ranking position of backward linkage for the Chenery-Watanabe method is comparably low, which is only 17. Auto-consumption is very high, since 26.88 percent of intermediate input comes from the sector itself and 23.7 percent of intermediate input comes from Primary metals (16), sector for which the value of backward linkages is relatively high. Therefore, it seems that the Chenery-Watanabe method underestimates the backward linkages in the case of Machinery.

For Electronics (21), the ranking of backward linkages given by the Chenery-Watanabe method and the Rasmussen method is relatively high (position 18 and position 14, respectively) in comparison with the other two methods. It can be found, in the 1997 input-output table, that 44.23 percent of total intermediate inputs for the electronics sector comes from the sector itself. The share of Electronics in total output, as well as in final demand, is not very high in 1997. Therefore, comparing with the pure-linkage method and the Dietzenbacher method (position 22 and 20), it appears that the Chenery-Watanabe method and the Rasmussen method overestimate the backward linkages of the electronics sector.

For Instruments (22), its share in total output, as well as in final demand are very small. The former induces a comparably high backward linkage for the Dietzenbacher method, and the latter induces a very low backward linkage for the pure-linkage method. So, it seems that there is an overestimation of backward linkages in the case of the Dietzenbacher and van der Linden method, and an underestimation in the case of the pure-linkage method in comparison with the Chenery-Watanabe and Rasmussen methods. The same phenomena also occurs in the cases of Maintenance (23) and Restaurants (28)

For Construction (25), its intermediate input ratio is 67.52 percent, which ranks at position 7 for the Chenery-Watanabe method. The main intermediate inputs are delivered by Building materials (26.73 percent), Primary metals (5.58 percent), and Metal products (5.6 percent). The rankings of these sectors are relatively high. On the other hand, the share of the construction sector in final demand is the highest (19.14 percent), and the intermediate consumption coming from itself is very low. So its rankings of backward linkages by the Diezenbacher & van der Linden method and the pure-linkage method are the highest. Therefore, it appears that the Chenery-Watanabe method underestimates the backward linkages of Construction.

Forward linkages

For Agriculture (1), its ranking of forward linkages as given by the pure-linkage method is very high. This can be attributed to the high share of agriculture in primary inputs. The input-output table shows that Agriculture delivers 54.35 percent of its output to intermediate consumption, of which 24 percent goes to the food sector, and 16.1 percent stays within the sector itself. For the food sector, only 37.17 percent of output remains in the production process. So the Chenery-Watanabe method, the Rasmussen method, as well as the Dietzenbacher and van der Linden method reported a relatively low forward linkage for the agricultural sector. Therefore, it seems that the pure-linkage method overestimates the forward linkage of agriculture sector. The same phenomena also occur in the food sector.

For Metal ore (4), 97.45 percent of its output remains in the production process, of which 64.1 percent goes to primary metals sector whose intermediate demand ratio is very high as well. So, the ranking position reported by the Chenery-Watanabe method is higher. The input-output table shows that the share of Metal ore in total output is very low (0.6%); this induces a higher value of forward linkage as found by the Dietzenbacher and van der Linden method. However, the ranking of forward linkages by the pure-linkage method is very low (position 21); this can be attributed to the lower share of the metal ore sector in total primary inputs. Therefore, it seems that the former three methods overestimate the forward linkages of Metal ore. The same phenomenon can also be found in the cases of Coal (2), Crude petroleum (3), other mining (5), Coking (13), and Maintenance (23).

For Textiles (7), the rankings of forward linkages given by the Chenery-Watanabe method and the Rasmussen method are at 15s, which is higher than that of the Dietzenbacher and van der Linden method, and lower than the Pure-linkage method. The input-output table shows that 70.54 percent of the textile sector's output is delivered to intermediate consumption purposes. A share of 34.39 percent remains in the sector itself, 18.7 percent goes to the clothing sector. So a small part of the output of the textile sector goes to the other production processes. Although Clothing relies heavily on the textile sector, it should be taken into account that the clothing sector has very low forward linkages according to the four methods. Therefore, it seems that there are some overestimations arising from the Chenery-Watanabe method, the Rasmussen method, and the pure-linkage method.

For Coking (13), 69.62 percent of its output is delivered to intermediate use, and 38.26 percent goes to the primary metal sector. There is a rather small part of its output remaining within the sector itself. It should be noted that the primary metal sector has a high forward linkage. So, comparing with the Rasmussen method and the Dietzenbacher & van der Linden method, it appears that the Chenery-Watanabe method, and especially the pure-linkage method underestimate the forward linkages for Coking. The underestimation of the pure-linkage method may be attributed to the lower share of the coking sector in total primary inputs.

For Chemicals (14), 82.82 percent of its output remains in the production process, of which 31.65 percent stays within the sector itself, 10 percent goes to Agriculture whose share in primary inputs is the highest. In addition, there are eight sectors for which the ratios of intermediate demand to the total output of Chemicals are relatively high. So, the ranking of the pure-linkage method is the highest. It appears that the other three methods underestimate the forward linkages in the case of the chemicals sector.

For Building materials (15), 86.79 percent of its output is for intermediate demand, of which 60.8 percent goes to the construction sector for which 94.1 percent of its output goes to final demand. This is to say that most of the Building materials' output quits the production process in the short term. Therefore, it seems that the Chenery-Watanabe method and the pure-linkage method overestimate forward linkages in the case of the building materials sector. The higher ranking position reported by the pure-linkage method is partly attributed to the relatively high shares of Building materials and Construction in total primary inputs.

For Commerce (27), 66.07 percent of commerce services is for production. For any individual sector, the greatest ratio of its delivery is 11.2 percent, and this is recorded for construction, a case where forward linkages are very low. Therefore, forward linkages of commerce are relatively low according to the Chenery-Watanabe method and the Rasmussen method. The ranking of the pure-linkage method is the highest among the four methods; this is attributed to the high share of Commerce in total primary inputs. So, it seems that the pure-linkage method overestimates the forward linkages of the commerce sector in comparison with the other three methods. The same phenomenon also occur in the cases of Freight transport (26) and Public utilities (30)

3.4 Overall Interdependence and Key sectors

Using the indices of overall intersectoral interdependence defined in section 2, we may measure the extent of intersectoral interdependence as a whole. The results are presented in Table 6. In terms of direct and total linkages, the pattern is the same, that is, the degree of intersectoral linkage in China increased gradually over the period of time 1987 to 1997. The direct and total impacts on output of a unitary change in final demand (or primary inputs) increased by 8.6 percent and 17.5 percent respectively between 1987 and 1997.

The increasing trend in overall intersectoral interdependence is also apparent in the results produced by the Dietzenbacher & van der Linden method and by the pure-linkage method though there is a small jump in 1995. The relative and pure effects on all input of the weighted average increased by 33.94 percent and 35.55 percent respectively. The relative and pure impacts on output increased by 31.55 percent and 34.16 percent respectively between 1987 and 1997. These increased trends of intersectoral linkages illustrate that intersectoral interconnections in the production process of China became tighter and tighter in parallel with the fast growth of the Chinese economy during the period 1987 to 1997.

Table 6 the indices of overall intersectoral interdependence

	1987	1990	1992	1995	1997
Backward linkage					
Chenery-Watanabe	0.5645	0.5813	0.6015	0.6114	0.6130
Rasmussen	2.2464	2.4076	2.5696	2.6333	2.6398
Dietzenbacher & vdL	3.0462	3.4988	4.0151	4.0080	4.0800
Pure-linkage	2.6423	3.0467	3.5844	3.5027	3.5817
Forward linkage					
Chenery-Watanabe	0.5645	0.5813	0.6015	0.6114	0.6130
Rasmussen	2.2464	2.4076	2.5696	2.6333	2.6398
Dietzenbacher & vdL	3.0314	3.4745	3.9649	3.9572	3.9878
Pure-linkage	2.5766	2.9670	3.5011	3.4145	3.4568

According to the size of the various linkage indicators, all sectors of an economy may be grouped into four categories. If the values of both backward linkage and forward linkage of a sector are all above the corresponding average, the sector is called as “key” sector. If only backward linkages (or forward linkages) of a sector are greater than the average, the sector can be termed a strong backward linkages (or strong forward linkages) sector. The fourth group refers to the weak linkages category; this is the case where a sector’s backward linkages and forward linkages are all less than the averages. Table 7 summarises the categorisation results for each method and time series. For each year, the pair of indicators falls in one of the four categories. The letters in these tables indicate which category a sector belongs to. The letters *K*, *B*, *F*, and *L* denote key sector, strong backward linkage, strong forward linkage, and weak linkage categories, respectively.

Table 7 shows that there are certain similarities between the results of the Chenery-Watanabe method and the Rasmussen method. But it is easy to find that there are some obvious differences between these results as reported by the four methods, especially in the category of key sectors.

Agriculture (1) is reported as being a key sector only by the pure-linkage method. For the other three methods, it falls in the weak linkage category.

For the mining industry (sector 2 to 5), there are strong forward linkages in general, as found by the Chenery-Watanabe method, the Rasmussen method and the Dietzenbacher & van der Linden method. But according to the pure-linkage method, they fall basically in the weak linkage category.

For the manufacturing industry, the pictures are very different between the four methods. According to the Chenery-Watanabe method, the key sectors include Textiles (7), Sawmills (9), Paper (10), Petroleum refining (12), Chemicals (14), Building materials (15), Primary metals (16), Instruments (22), and Other industries (24). Electricity (11) has strong forward linkages. Basically, the other manufacturing sectors fall in the strong backward linkage group.

According to the Rasmussen method, in general, the key sectors are Textiles (7), Coking (13), Chemicals (14), Primary metals (16), Instruments (22), and Other industries (24). Electricity (11) and Petroleum refining (12) have strong forward linkages. Food (6) is a weak linkage sector except for 1987. The rest of the manufacturing sectors falls in the strong backward linkage category.

According to the Dietzenbacher and van der Linden method, Coking (13) is clearly a key sector. Basically, Instruments (22) and Maintenance (23) also are key sectors. In addition, Petroleum refining (12) is reported as a key sector in 1992, 1995 and 1997. Food (6) and Electronics (21) belong to weak linkage sectors. The rest of the manufacturing sectors falls in the strong backward linkages category.

For the pure-linkage method, Chemicals (14), Building materials (15), Primary metals (16), Machinery (18) and Commerce (27) are clearly key sectors. Except for 1997, Textiles (7) is also a key sector. Food (6), Clothing (8), as well as Metals products (17) and Electrical machinery (20) except for 1995 and 1997, are strong backward linkage sectors. Electricity (11) and Petroleum refining (12) are basically strong forward linkages sectors. In general, the rest of manufacturing sectors falls in the weak linkage category.

For the services sectors, there are four sectors that are in the weak linkages category in general, according to all four methods during the period of time considered. These are Restaurants (28), Passenger transport (29), Public utilities (30), and Public administration (33). Culture (31) falls in the weak linkage category for the Chenery-Watanabe method, the Rasmussen method, and the Dietzenbacher method. But according to the pure-linkage method, it is a strong backward linkages sector. Basically, Freight transport (26) and Commerce (27) belong to the key sectors category for the pure-linkage method, but it falls in the strong forward linkage category for other three methods. Finance (32) is clearly a strong forward linkage sector for the Chenery-Watanabe method and the Rasmussen method during the entire period of time reviewed, but in general it is a weak linkages sector according to the Dietzenbacher and van der Linden method and the pure-linkage method.

4 Conclusions

This paper examined the change in intersectoral linkages in the Chinese economy over the period of time 1987 to 1997 using four linkage analysis methods. As has been seen above, there exist some dissimilarities and similarities between the results derived from the four methods. The four different methods depict the impact of each sector in the production process and the intersectoral interconnections under different aspects. The main conclusions are fourfold:

First, various linkage indicators derived from input-output tables and the different measures show an increasing degree of intersectoral interdependence in the case of the Chinese economy in parallel with high economic growth rates during the decade. Overall, indices of intersectoral interdependence also exhibit an increasing trend. In addition, there are increasing trends in terms of the averages of various forward linkages, as well as the averages of total, relative and pure backward linkage indicators, with the exception of an individual year. This indicates that there is a positive relationship between the growth of production activities and the increase in intersectoral interdependence in China during the period of time reviewed.

Second, high total linkages are concentrated mainly in Mining, Manufacturing, and Construction, while low total linkage effects are found in agriculture and service sector. That means that the mining sector, the construction sector, and moreover the manufacturing sector are dominant in the Chinese economy over the decade studied.

Third, the identification of key sectors in the Chinese economy is very different between the four methods. Key sectors identified clearly by the Chenery-Watanabe method throughout the entire period include Petroleum refining, Chemicals, Building materials, Primary metals, and Metal products. According to the total linkage indicators, only two sectors, Chemical and Primary metals, are clearly key sectors throughout the entire period. For the Dietzenbacher and van der Linden method, only Coking is clearly a key sector. The pure linkage indicators give a different identification of key sector. The difference is that Agriculture and one services sector, Commerce, are identified as key sectors. The reason is that the share of each sector in final demand and primary inputs is taken into account by the pure-linkage measures. In addition, some manufacturing sectors, including Chemicals, Building materials, Primary metals, and Machinery, are viewed as key sectors by the pure-linkage method.

Finally, through the results discussed above, it is easy to find that the differences between the four methods are obvious in the ranking of linkage indicators, and in the identification of key sectors. The Chenery-Watanabe method is based on the direct input and output coefficients of all sectors. So, some sectors producing primary products and intermediate products, such as Metal ore, Petroleum refining, Primary metals, etc., would have relatively high forward linkages. Some sectors that mainly produce the final demand products and services, such as Food, Clothing, Public utilities, etc., would obtain relatively low forward linkages. This is partly held in the Rasmussen method though the indirect linkage is taken into account. However, it is not held in the Dietzenbacher and van der Linden method and the pure-linkage method. The former is based on the ratio of each sector's effects to the output of the sector. So, the relative high output would induce a lower linkage in some sectors, such as Agriculture, Food, Chemicals, etc. The latter considers the share of each sector in final demand and in primary inputs, while eliminating the self-impact of each sector. Therefore, some sectors that have relative high shares in final demand (or primary inputs) would have higher backward linkages (or forward linkages).

The Chenery-Watanabe indices and the Rasmussen indices are used to examine how the internal structure of the economy behaved and changed, without taking into account the level and structure of production in each sector. On the other hand, the Diezenbacher indices and the pure linkage indices are used to explore the production structure when the level of production and the structure of final demand and primary inputs (GDP) are taken into consideration. The first two kinds of analyses concerning the behaviour and change of coefficients are important for defining key economic sectors in the internal structure of the economy. On the other hand, the latter two measures also are important for determining which sectors will be the mainly responsible for the growth of overall output and GDP in the economy. Therefore, these methods need to be combined to examine the structural change of the Chinese economy in terms of intersectoral interdependence analysis. As has been shown above, the consequences obtained are complementary to each other.

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Table 3 Backward linkages resulting from the various methods

Sector	Chenery-Watanabe					Rasmussen					Dietzenbacher & vdL					Pure linkage				
	1987	1990	1992	1995	1997	1987	1990	1992	1995	1997	1987	1990	1992	1995	1997	1987	1990	1992	1995	1997
1	0.315	0.343	0.356	0.402	0.403	1.621	1.712	1.834	1.951	1.967	0.417	0.458	0.610	0.655	0.679	0.135	0.150	0.178	0.184	0.182
2	0.401	0.538	0.561	0.470	0.486	1.908	2.412	2.497	2.266	2.311	0.882	1.373	1.409	1.219	1.242	0.020	0.041	0.037	0.026	0.035
3	0.241	0.351	0.378	0.398	0.262	1.571	1.950	2.020	2.103	1.715	0.562	0.940	0.986	1.069	0.696	0.013	0.019	0.022	0.026	0.014
4	0.483	0.566	0.607	0.622	0.646	2.064	2.432	2.586	2.645	2.743	0.961	1.243	1.362	1.448	1.420	0.007	0.011	0.011	0.017	0.019
5	0.374	0.518	0.558	0.548	0.542	1.806	2.262	2.469	2.454	2.396	0.789	1.231	1.385	1.360	1.296	0.014	0.029	0.032	0.041	0.035
6	0.737	0.723	0.743	0.657	0.723	2.345	2.374	2.604	2.441	2.609	1.149	1.208	1.399	1.226	1.335	0.162	0.183	0.194	0.194	0.212
7	0.744	0.767	0.794	0.809	0.718	2.710	2.905	3.162	3.290	2.929	1.052	1.132	1.337	1.340	1.164	0.097	0.115	0.136	0.124	0.094
8	0.713	0.744	0.788	0.787	0.688	2.697	2.922	3.225	3.372	2.912	1.558	1.775	2.106	2.005	1.689	0.060	0.086	0.117	0.177	0.127
9	0.682	0.706	0.747	0.727	0.721	2.569	2.830	3.067	3.005	2.980	1.349	1.582	1.721	1.660	1.505	0.023	0.027	0.028	0.040	0.037
10	0.665	0.703	0.730	0.753	0.685	2.518	2.760	2.965	3.124	2.868	1.167	1.366	1.577	1.492	1.399	0.054	0.077	0.091	0.087	0.067
11	0.424	0.523	0.512	0.516	0.568	1.842	2.268	2.293	2.266	2.425	0.809	1.209	1.224	1.197	1.328	0.027	0.048	0.052	0.056	0.065
12	0.563	0.635	0.718	0.720	0.780	1.931	2.312	2.537	2.602	2.536	0.906	1.263	1.470	1.512	1.422	0.028	0.042	0.044	0.055	0.050
13	0.805	0.748	0.775	0.856	0.760	2.631	2.831	2.936	3.067	2.821	1.585	1.778	1.886	2.018	1.771	0.008	0.012	0.012	0.013	0.010
14	0.676	0.705	0.721	0.743	0.731	2.506	2.727	2.919	3.094	2.998	1.023	1.194	1.254	1.210	1.195	0.112	0.164	0.166	0.160	0.159
15	0.590	0.642	0.653	0.670	0.684	2.307	2.646	2.729	2.786	2.822	1.196	1.431	1.515	1.531	1.532	0.078	0.117	0.132	0.145	0.160
16	0.677	0.738	0.715	0.732	0.796	2.571	2.976	2.926	2.987	3.267	1.096	1.372	1.288	1.334	1.511	0.075	0.116	0.114	0.135	0.121
17	0.675	0.711	0.760	0.763	0.767	2.632	2.949	3.143	3.167	3.270	1.517	1.764	1.956	1.923	1.916	0.061	0.086	0.100	0.106	0.116
18	0.648	0.694	0.717	0.728	0.664	2.576	2.904	3.030	3.093	2.965	1.214	1.436	1.537	1.591	1.517	0.121	0.141	0.184	0.175	0.140
19	0.701	0.722	0.733	0.759	0.738	2.758	3.020	3.114	3.262	3.248	1.352	1.538	1.575	1.606	1.578	0.039	0.049	0.076	0.090	0.090
20	0.705	0.727	0.746	0.754	0.777	2.720	3.003	3.115	3.192	3.349	1.474	1.690	1.787	1.757	2.008	0.069	0.084	0.094	0.104	0.137
21	0.718	0.739	0.750	0.726	0.746	2.886	3.140	3.175	3.150	3.336	1.108	1.270	1.437	1.300	1.387	0.024	0.033	0.043	0.057	0.063
22	0.574	0.663	0.661	0.680	0.687	2.394	2.826	2.860	2.945	3.058	1.255	1.701	1.667	1.736	1.912	0.008	0.016	0.012	0.010	0.020
23	0.612	0.660	0.697	0.670	0.583	2.506	2.805	2.994	2.982	2.724	1.502	1.801	1.962	1.865	1.627	0.018	0.021	0.022	0.015	0.015
24	0.676	0.743	0.762	0.754	0.553	2.625	3.042	3.110	3.103	2.483	1.399	1.577	1.795	2.015	1.363	0.012	0.030	0.049	0.013	0.048
25	0.714	0.715	0.704	0.710	0.713	2.677	2.901	2.941	2.975	3.008	1.677	1.901	1.920	1.951	1.992	0.357	0.330	0.373	0.437	0.456
26	0.369	0.402	0.435	0.418	0.431	1.813	2.050	2.172	2.149	2.171	0.795	1.005	1.122	1.098	1.100	0.046	0.084	0.080	0.076	0.078
27	0.463	0.552	0.533	0.438	0.490	1.846	2.107	2.326	2.042	2.286	0.809	1.051	1.184	0.974	1.137	0.069	0.074	0.223	0.146	0.149
28	0.725	0.697	0.598	0.607	0.644	2.466	2.466	2.400	2.403	2.519	1.466	1.466	1.400	1.392	1.508	0.036	0.034	0.043	0.034	0.045
29	0.385	0.420	0.455	0.414	0.485	1.870	2.075	2.230	2.132	2.292	0.865	1.076	1.220	1.124	1.277	0.011	0.022	0.031	0.019	0.023
30	0.281	0.303	0.415	0.408	0.513	1.631	1.764	2.089	2.074	2.393	0.627	0.765	1.030	1.023	1.274	0.031	0.035	0.075	0.071	0.118
31	0.535	0.577	0.465	0.477	0.522	2.213	2.442	2.241	2.300	2.413	1.152	1.358	1.206	1.265	1.364	0.112	0.129	0.101	0.093	0.116
32	0.060	0.069	0.478	0.383	0.390	1.110	1.143	2.195	1.963	1.958	0.108	0.141	1.138	0.942	0.864	0.004	0.006	0.070	0.038	0.036
33	0.360	0.346	0.522	0.522	0.549	1.771	1.847	2.350	2.361	2.422	0.770	0.847	1.350	1.361	1.422	0.026	0.030	0.097	0.078	0.083
Average	0.554	0.597	0.630	0.625	0.619	2.245	2.509	2.674	2.689	2.673	1.079	1.301	1.449	1.430	1.407	0.059	0.074	0.092	0.092	0.095

Table 4 Forward linkages resulting from the various methods

Sector	Chenery-Watanabe					Rasmussen					Dietzenbacher & vdL					Pure linkage				
	1987	1990	1992	1995	1997	1987	1990	1992	1995	1997	1987	1990	1992	1995	1997	1987	1990	1992	1995	1997
1	0.466	0.538	0.491	0.544	0.544	1.904	2.148	2.019	2.235	2.210	0.741	0.900	0.845	0.974	0.959	0.230	0.300	0.230	0.261	0.245
2	0.844	0.701	0.798	0.845	0.960	3.566	3.303	3.745	3.831	4.330	2.490	2.229	2.583	2.726	3.154	0.059	0.067	0.069	0.060	0.091
3	0.843	0.861	1.020	0.994	1.196	3.769	4.021	4.927	4.821	5.869	2.726	2.973	3.798	3.703	4.739	0.063	0.061	0.086	0.093	0.102
4	1.104	1.227	1.184	1.149	1.142	5.037	5.663	6.085	5.484	6.015	3.646	4.027	4.367	3.946	4.085	0.028	0.038	0.037	0.048	0.062
5	1.021	1.059	0.996	0.859	0.946	2.826	3.449	3.470	3.097	3.498	1.787	2.375	2.329	1.961	2.320	0.033	0.056	0.055	0.060	0.064
6	0.327	0.301	0.348	0.338	0.372	1.581	1.586	1.726	1.756	1.800	0.497	0.515	0.634	0.643	0.664	0.057	0.066	0.077	0.089	0.090
7	0.636	0.706	0.693	0.891	0.787	2.531	2.859	2.713	3.453	3.119	0.941	1.102	1.059	1.436	1.279	0.081	0.111	0.097	0.137	0.108
8	0.236	0.218	0.132	0.228	0.231	1.482	1.493	1.289	1.430	1.503	0.443	0.455	0.273	0.363	0.445	0.015	0.019	0.012	0.020	0.026
9	0.801	0.737	0.738	0.711	0.671	2.517	2.541	2.649	2.495	2.504	1.304	1.326	1.373	1.238	1.143	0.022	0.022	0.022	0.028	0.027
10	0.751	0.721	0.671	0.693	0.854	2.696	2.728	2.698	2.844	3.269	1.304	1.325	1.362	1.296	1.699	0.062	0.075	0.077	0.073	0.085
11	0.915	0.948	0.937	0.827	0.928	3.496	3.806	3.986	3.614	4.010	2.398	2.657	2.827	2.470	2.807	0.081	0.108	0.123	0.119	0.141
12	0.964	0.951	1.032	1.017	1.105	3.265	3.495	3.958	3.975	4.114	2.202	2.389	2.829	2.808	2.883	0.069	0.082	0.087	0.104	0.104
13	0.762	0.778	0.619	0.550	0.698	3.466	3.608	3.178	2.858	3.615	2.397	2.523	2.121	1.814	2.544	0.013	0.017	0.014	0.012	0.015
14	0.938	0.905	0.917	0.956	0.956	3.329	3.461	3.577	3.970	3.930	1.582	1.687	1.685	1.715	1.753	0.200	0.258	0.244	0.263	0.271
15	1.012	0.936	0.895	0.868	0.879	2.491	2.649	2.831	2.732	2.588	1.364	1.429	1.604	1.484	1.336	0.090	0.117	0.141	0.140	0.137
16	1.129	1.022	1.157	1.051	1.105	3.646	3.700	4.438	4.053	4.411	1.846	1.867	2.299	2.049	2.273	0.147	0.171	0.234	0.232	0.199
17	0.763	0.694	0.771	0.820	0.796	2.423	2.565	2.745	2.870	2.947	1.322	1.411	1.593	1.660	1.644	0.053	0.068	0.081	0.091	0.098
18	0.541	0.582	0.630	0.630	0.684	2.209	2.518	2.724	2.777	2.958	0.931	1.141	1.306	1.351	1.511	0.086	0.107	0.151	0.144	0.139
19	0.587	0.652	0.719	0.613	0.567	2.230	2.623	2.922	2.667	2.553	0.946	1.231	1.432	1.183	1.090	0.025	0.038	0.068	0.061	0.056
20	0.589	0.633	0.649	0.727	0.661	2.225	2.556	2.677	2.930	2.720	1.050	1.308	1.417	1.547	1.470	0.047	0.063	0.073	0.090	0.097
21	0.555	0.552	0.553	0.546	0.710	2.220	2.252	2.367	2.328	3.042	0.717	0.739	0.903	0.803	1.212	0.010	0.013	0.022	0.026	0.052
22	0.986	0.624	0.924	1.137	0.787	3.241	2.529	3.738	4.549	3.198	2.018	1.406	2.453	3.168	2.042	0.013	0.013	0.018	0.018	0.022
23	0.087	0.100	0.264	1.000	1.024	1.192	1.246	1.647	3.618	3.826	0.191	0.245	0.636	2.464	2.666	0.002	0.003	0.007	0.020	0.025
24	1.095	0.996	0.993	0.964	0.680	3.517	3.725	3.868	3.746	3.161	2.168	2.093	2.440	2.631	1.986	0.019	0.042	0.068	0.017	0.072
25	0.000	0.000	0.045	0.037	0.059	1.000	1.000	1.091	1.072	1.130	0.000	0.000	0.090	0.071	0.129	0.000	0.000	0.015	0.013	0.028
26	0.641	0.698	0.861	0.873	0.834	2.306	2.653	3.325	3.424	3.254	1.277	1.575	2.226	2.316	2.118	0.075	0.134	0.163	0.164	0.154
27	0.834	0.790	0.755	0.806	0.661	2.861	2.950	2.985	3.227	2.744	1.779	1.841	1.772	2.080	1.543	0.157	0.134	0.345	0.323	0.208
28	0.000	0.000	0.000	0.360	0.529	1.000	1.000	1.000	1.891	2.357	0.000	0.000	0.000	0.884	1.347	0.000	0.000	0.000	0.022	0.040
29	0.467	0.509	0.403	0.635	0.613	1.873	2.057	1.973	2.557	2.230	0.868	1.045	0.966	1.545	1.216	0.012	0.022	0.024	0.026	0.022
30	0.230	0.247	0.588	0.458	0.544	1.426	1.496	2.607	2.198	2.336	0.423	0.493	1.520	1.141	1.221	0.021	0.023	0.113	0.079	0.112
31	0.211	0.230	0.225	0.226	0.196	1.435	1.518	1.559	1.577	1.445	0.413	0.486	0.543	0.562	0.429	0.037	0.042	0.044	0.040	0.034
32	0.979	0.909	0.977	0.810	0.749	3.528	3.476	3.872	3.336	3.123	2.492	2.441	2.734	2.285	1.916	0.103	0.107	0.173	0.094	0.086
33	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average	0.646	0.631	0.666	0.702	0.711	2.524	2.657	2.891	2.982	3.055	1.341	1.431	1.637	1.707	1.746	0.058	0.072	0.090	0.090	0.091

Table 5 Ranking of backward linkages for 1997

		Backward linkages				Forward linkages			
		C&W	RAS	D&V	PUR	C&W	RAS	D&V	PUR
1	Agriculture	31	31	33	3	27	28	28	2
2	Coal	28	27	26	26	6	4	3	15
3	Crude petroleum	33	33	32	32	1	2	1	12
4	Metal ore	18	16	16	30	2	1	2	21
5	Other mining	24	25	23	27	8	10	8	20
6	Food	9	18	21	2	29	29	29	16
7	Textiles	11	11	28	14	15	16	22	10
8	Clothing	13	12	6	9	30	30	30	28
9	Sawmills	10	9	13	24	21	24	26	27
10	Paper	15	13	17	18	11	11	15	18
11	Electricity	21	22	22	19	9	6	5	6
12	Petroleum refining	2	19	15	21	3	5	4	11
13	Coking	5	15	5	33	18	9	7	32
14	Chemicals	8	8	27	5	7	7	14	1
15	Building materials	16	14	9	4	10	22	21	8
16	Primary metals	1	4	11	10	4	3	9	4
17	Metal products	4	3	3	12	13	19	16	13
18	Machinery	17	10	10	7	19	18	18	7
19	Transport equipment	7	5	8	15	25	23	27	22
20	Electrical machinery	3	1	1	8	22	21	19	14
21	Electronics	6	2	18	20	17	17	25	23
22	Instruments	14	6	4	29	14	13	11	30
23	Maintenance	20	17	7	31	5	8	6	29
24	Other industries	22	21	20	22	20	14	12	19
25	Construction	12	7	2	1	32	32	32	26
26	Freight transport	30	30	30	17	12	12	10	5
27	Commerce	27	29	29	6	23	20	17	3
28	Restaurants	19	20	12	23	28	25	20	24
29	Passenger transport	29	28	24	28	24	27	24	31
30	Public utilities	26	26	25	11	26	26	23	9
31	Culture	25	24	19	13	31	31	31	25
32	Finance	32	32	31	25	16	15	13	17
33	Public administration	23	23	14	16	33	33	33	33

Table 7 Categorisation of sectors for the four methods

		Chenery-Watanabe					Rasmussen					Dietzenbacher & vdL					Pure linkage				
		1987	1990	1992	1995	1997	1987	1990	1992	1995	1997	1987	1990	1992	1995	1997	1987	1990	1992	1995	1997
1	Agriculture	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	K	K	K	K	K
2	Coal	F	F	F	F	F	F	F	F	F	F	F	K	F	F	F	F	L	L	L	L
3	Crude petroleum	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	L	L	F	F
4	Metal ore	F	F	F	F	K	F	F	F	F	K	F	F	F	K	K	L	L	L	L	L
5	Other mining	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	L	L	L	L	L
6	Food	B	B	B	B	B	B	L	L	L	L	B	L	L	L	L	B	B	B	B	B
7	Textiles	B	K	K	K	K	K	K	B	K	K	L	L	L	L	L	K	K	K	K	F
8	Clothing	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
9	Sawmills	K	K	K	K	B	B	B	B	B	B	B	B	B	B	B	L	L	L	L	L
10	Paper	K	K	K	B	K	K	K	B	B	K	B	B	B	B	L	F	K	L	L	L
11	Electricity	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
12	Petroleum refining	K	K	K	K	K	F	F	F	F	F	F	F	K	K	K	F	F	L	F	F
13	Coking	K	K	B	B	B	K	K	K	B	K	K	K	K	K	K	L	L	L	L	L
14	Chemicals	K	K	K	K	K	K	K	K	K	K	F	F	F	F	F	K	K	K	K	K
15	Building materials	K	K	K	K	K	B	B	B	B	B	K	B	B	B	B	K	K	K	K	K
16	Primary metals	K	K	K	K	K	K	K	K	K	K	K	K	F	F	K	K	K	K	K	K
17	Metal products	K	K	K	K	K	B	B	B	B	B	B	B	B	B	B	B	B	B	K	K
18	Machinery	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	K	K	K	K	K
19	Transport equipment	B	K	K	B	B	B	B	K	B	B	B	B	B	B	B	L	L	L	L	L
20	Electrical machinery	B	K	B	K	B	B	B	B	B	B	B	B	B	B	B	B	B	B	K	K
21	Electronics	B	B	B	B	B	B	B	B	B	B	B	L	L	L	L	L	L	L	L	L
22	Instruments	K	B	K	K	K	K	B	K	K	K	K	B	K	K	K	L	L	L	L	L
23	Maintenance	B	B	B	K	F	B	B	B	K	K	B	B	B	K	K	L	L	L	L	L
24	Other industries	K	K	K	K	L	K	K	K	K	F	K	K	K	K	F	L	L	L	L	L
25	Construction	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
26	Freight transport	L	F	F	F	F	L	L	F	F	F	L	F	F	F	F	F	K	F	F	F
27	Commerce	F	F	F	F	L	F	F	F	F	L	F	F	F	F	L	K	K	K	K	K
28	Restaurants	B	B	L	L	B	B	L	L	L	L	B	B	L	L	B	L	L	L	L	L
29	Passenger transport	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
30	Public utilities	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	F	L	K
31	Culture	L	L	L	L	L	L	L	L	L	L	B	B	L	L	L	B	B	B	B	B
32	Finance	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	L
33	Public administration	L	L	L	L	L	L	L	L	L	L	L	L	L	L	B	L	L	B	L	L

Appendix: Specification of industry labels

No.	Label	Sector
1	Agriculture	Agricultural, forestry and fishing products
2	Coal	Coal mining
3	Crude petroleum	Crude petroleum and natural gas production
4	Metal ore	Metal ore mining
5	Other mining	Other mining
6	Food	Food
7	Textiles	Textiles
8	Clothing	Clothing and leather
9	Sawmills	Sawmills and manufacture of furniture
10	Paper	Paper, cultural and educational articles
11	Electricity	Electricity, steam and hot water production and supply
12	Petroleum refining	Petroleum refining
13	Coking	Coking, manufacture of gas coal products
14	Chemicals	Chemicals
15	Building materials	Building materials and other non-metallic mineral products
16	Primary metals	Primary metals
17	Metal products	Metal products
18	Machinery	Machinery
19	Transport equipment	Transport equipment
20	Electrical machinery	Electrical machinery and instruments
21	Electronics	Electronics and communication equipment
22	Instruments	Instrument, meters and other measuring equipment
23	Maintenance	Maintenance and repair of machinery and equipment
24	Other industries	Industries not elsewhere classified
25	Construction	Construction
26	Freight transport	Freight transport and communication
27	Commerce	Commerce
28	Restaurants	Restaurants
29	Passenger transport	Passenger transport
30	Public utilities	Public utilities and services to household
31	Culture	Cultural, education health and scientific research institutions
32	Finance	Finance and insurance
33	Public administration	Public administration