

# **An Analysis of Input-output Interindustry Linkages in the PRC Economy**

by

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## **Abstract**

The key backward and forward linkage industries in the PRC economy are identified by applying two extraction modelling techniques to the PRC's 1997 Input-output model. The application of the first model (Model 1) identifies the following as both key backward and forward linkage sectors: the two energy sectors, namely, coking, gas, petroleum refining (CGPR) and power, steam, hot water (PSHW) plus metal production (METAL) while building materials and non-metallic products (BMNM) and other services (OTSV) are also key backward linkage sectors. Model 1 also suggests that mining and quarrying (MNQR), chemicals (CHEM) and transport-telecommunications (TRANTEL) are also key forward linkage sectors. Model 2 varies model 1 by weighting linkage effects by each industry's contribution to the PRC's GDP. Model 2 indicates that in addition to CGPR, commercial trade (COMCT) and PSHW, agriculture (AGRI) of the PRC economy remains a key backward and forward linkage sector. The overall picture is that energy and infrastructure sectors have joined Agriculture as a key linkage sector in China's developing economy.

Key words: Input-output, coefficients, extraction, backward linkages, forward linkages  
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## **1. Introduction**

The emergence of the People's Republic of China (PRC) as a major world economic power was hastened by its reintegration with Hong Kong in 1997 and by its acceptance as a member of the WTO in 2001. Currently, the world's fourth largest economy still has many of the attributes of a developing country and the question remains: Is the structure of the PRC economy sufficiently mature to maintain pre Asian currency crisis growth rates? One answer to this question is to be found in a linkage analysis of the PRC's industrial structure. A linkage analysis enables researchers to identify those industries or sectors of the economy which are the major drivers of economic growth. Since the seminal analysis by Hirschman(1958), interindustry interdependencies(linkages) are defined in backward and forward directions from an input output model of the economy. In relation to backward linkages, the concern is to identify how some sectors depend on others for their input supplies. Forward linkages identify those key sectors who distribute their outputs as inputs to other industries further down the value added chain of national production. Those key buyer and seller industries can constitute the potential growth core of the economy. In the case of the so called third world countries, the agricultural sector often forms the development core of the economy. How far has the PRC economy advanced in relation to the diversity of its core industry base, or is it that the agricultural sector still dominates the development core?

The purpose of this study is to conduct both backward and forward linkage analyses to determine the key growth sectors of the PRC economy. This goal is pursued by modifying some recent techniques for assessing industry contributions to the national economy. The modification takes the form of applying a particular weighting pattern to unweighted backward and forward linkages. These weights are designed to reflect the relative contribution of individual industries to the PRC economy.

## 2. Unweighted and weighted linkages

An input output (I/O) model of a particular national economy or region may be represented in the following way:

$$X = (I - A)^{-1} f \quad (1)$$

where  $X$  is an  $n$  element industry output vector,  $f$  is an  $n$  element industry final demand vector,  $A$  is an  $n \times n$  input coefficient matrix and  $i$  is an  $n$  dimensional identity matrix.

Hirschman(1958) developed the idea of interindustry linkages in this I/O framework.

Backward linkages represent the dependence of some industries on others supplying their inputs while forward linkages identify the amount of output supplied forward by some industries to others in the I/O chain. Chenery and Watanabe (1958) devised backward linkage indices using the column sums of the input matrix  $A$ , while Rasmussen (1956) measured

backward linkages as the column sum of the Leontieff inverse matrix:  $(I - A)^{-1}$ . The

limitations of these definitions is that they were defined in terms of backward linkages only and were not clearly distinguished from forward linkages. The distinction between backward

and forward linkages is classified in Strassert's (1968) extraction method where the outputs generated by the I/O model summarised in expression (1) are re-estimated without one

industry present in the economy. This approach involves the deletion of that industry's row

and column from the matrix of input-output coefficients  $a$  and its final demand from the

vector  $f$ . This leaves a reduced  $(n-1) \times (n-1)$  input matrix  $\bar{A}$  and an  $(n-1)$  final demand vector

$\bar{f}$ . The output vector is recalculated according to expression (1) and the difference between

the  $n$  and  $n-1$  industry outputs are calculated and summed to determine the output loss to the economy flowing from the withdrawal of this individual industry.

Strassert's methodology is subject to an important limitation, namely, that it measures total linkage effects without taking into account the difference between forward and

backward linkages. Dietzenbacher and Van de Linden (1997) modify Strassert's approach to

allow the separate measurement of backward and forward linkages and further they develop both relative and absolute measures of backward and forward linkages. Relative linkage measures are applied in this study and are defined in the following:

$$RBL = 100 \sum_{i=1}^n [X_i - X_i(-j) / X_j] \quad (2)$$

$X_i$  is the output of industry I when all n industries are included in this economy and  $X_i(-j)$  is the output of each industry i, when industry j is does not depend on any other industry in domestic economy for input purchase. This output,  $X_i(-j)$  is defined by the following:

$$X_i(-j) = [I - A(-j)]^{-1} f \quad (3)$$

$X(-j)$  is the vector of outputs when industry j buys no inputs modestically,  $A(-j)$  the input coefficient matrix modified so that all elements the jth row are zero and f is the final demand vector. Relative backward linkages (RBL) differ from absolute backward linkages (ABL)

which are simply defined as the sum of output differences:  $\sum_{i=1}^n [X_i - X_i(-j)]$ . The results for

the PRC's ABL are not reported here.<sup>1</sup>

Dietzenbacher and Van de Linden's interpretation of relative forward linkages (RFL) is defined in a corresponding manner:

$$RFL = 100 \sum_{i=1}^n [X_i - X_i(-j) / X_j] \quad (4)$$

However in the case of the RFL, the revised output vector  $X_i(-j)$  reflects the forward nature of industry linkages:

$$X_i'(-j) = V'[I - B(-j)]^{-1} \quad (5)$$

The differences between RBL and RFL are evident in the comparison of expressions (5) and (3). In (5) the  $n \times n$  output coefficient matrix (B) replaces the input matrix A in (3) and the

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<sup>1</sup> These are available from the authors upon request, but do not add greatly to the interpretation of the results of this study.

final demand vector  $f$  in (3) is replaced by the vector  $V$  of primary inputs, the value added by industry plus imports.

Absolute forward linkages are calculated in the following manner:  $\sum_{i=1}^n [X_i - X_i(-j)]$ .

For the economy as a whole backward linkages are the summation of the difference between  $X_i$  and  $X_i(-j)$  where  $X_i$  is industry  $i$ 's output defined in terms of the output coefficient matrix  $B$ :

$$X_i' = V'(I - B)^{-1} \quad (6)$$

The expressions (2) and (4) taken together, are described as Model 1 throughout the remainder of the study. An important characteristic of Model 1 is that the calculation of RBL and RFL fail to accommodate the relative importance of individual industries in the economy in the sense of their proportional contribution to the national GDP of China. Model 1 is hereafter referred to as the unweighted as the unweighted RFL model. Model 1 is open to the criticism by Laumas(1976) that linkages should be adjusted for the relative importance of individual industries to the national economy. The calculation of RBL and RFL should take into account the relative importance of each industry. In effect model 1 comprised of expressions (2) and (4) takes no account of relative industry contributions to the national economy. The novel aspect of this study is its treatment of this weighting problem. A second interpretation of RBL and RFL is developed by weighting the final demands in (2) and the primary inputs in (4) by industry  $i$ 's value added to the GDP of the nation. The weights are ratios of each industry  $i$  value added ( $A_i$ ) to China's GDP as follows:  $W_i = A_i / \sum_{i=1}^n A_i$ . These weights are applied to the vector of final demands and primary inputs in relation to the RBL and RFL calculations respectively. The extraction method is then applied but is based on the weighted final demands and primary inputs which are defined in the following manner:

$$fs_i = W_i f_i \quad (7)$$

$$Vs_i = W_i V_i \quad (8)$$

Model 2 (the weighted alternative) is comprised of the definitions of the RBL and RFL in expressions (2) and (4) but these are now based on outputs ( $X_i^{fs}, X_i^{vs}$ ) from weighted final demands and weighted primary inputs as follows. The weighted relative backward and forward linkages are indicated by the symbol \*. A formal statement of the weighted model 2 is summarised in the following:

$$RBL^* = 100 \sum_{i=1}^n [(X_i^{fs} - X_i^{fs}(-j)) / X_j^{fs}] \quad (9)$$

where outputs before and after extraction are determined by:

$$X_i^{fs} = (I - A)^{-1} fs \quad (10)$$

$$X_i^{fs}(-j) = [(I - A(-j))]^{-1} fs \quad (11)$$

In relation to relative forward linkages:

$$RFL^* = 100 \sum_{i=1}^n [(X_i^{vs} - X_i^{vs}(-j)) / X_j^{vs}] \quad (12)$$

where outputs are determined as follows:

$$X_i^{vs} = Vs'(I - B)^{-1} \quad (13)$$

$$X_i^{vs}(-j) = Vs'[(I - B(-j))]^{-1} \quad (14)$$

The unweighted Model 1 and weighted model 2 are applied to the national 17×17 I/O model for the People's Republic of China to identify the key interindustry linkages in the world fourth largest economy. The outcomes of this analysis will be used to determine if the key sectors of the Chinese economy are still the traditional ones which typify developing nations or if China's modernisation has advanced to the point where new age activities are of greater significance in securing the industry network of china.

### **3. PRC data**

A national I/O model for the Chinese economy has been developed by the Chinese Statistical Bureau. The I/O table for this model is dated 1997 and is published in the China Statistical Yearbook 2000. Further, there is a separate report of value added by each of the seventeen industry sectors contained in the China Industry Statistical Yearbook 2000 also prepared by the Chinese Statistical Bureau. These are used to determine the industry weights  $W_i$  employed in Model 2. Full details of these data sources are provided at the end of the text. The following seventeen industry groups constitute the PRC I/O model:

Agriculture, forestry and fishing (AGRI), Mining and quarrying (MNQR) Food and beverage processing and manufacturing (FOOD); Textile, sewing, leather & fur products(TEXTL); Paper making, educational appliance, repairing(OTMF); Production of power, steam and hot water(PSHW); Coking, gas and petroleum refining(CGPR); Chemical raw material and products, medicine, chemical fibre, rubber and plastic(CHEM); Building materials and non-metallic minerals(BMNM); Metal products(METAL); Machine and equipment(MACH); Building and construction(CONS); transportation, post and telecommunication(TRANTEL); Commerce and catering trade(COMCT); Public utilities and resident services (PURS); Banking and insurance(BANKI); other services: educational, research, scientific, cultural and media (OTSV).

This is a small table for an economy as complex as the PRC's, however it provides a sufficiently detailed industry grid to serve the purposes of the study.

### **4. Backward and Forward Linkages in the PRC: Results**

Backward linkages for each of the 17 PRC industries are represented on table 1. The results pertain to both the unweighted model 1 and the weighted model 2. Relative backward

linkages are expressed on table 1 as percentages and are calculated by the use of expressions (2) and (9) for models 1 and 2 respectively.

**Table 1: Relative Backward and Forward Linkages: PRC economy**

Industry	Backward Linkages				Forward Linkages			
	Expression (2)		Expression (9)		Expression (4)		Expression (12)	
	RBL <sup>2</sup>	Rank	RBL*	Rank	RFL	Rank	RFL*	Rank
	%	No.	%	No	%	No.	%	No
1.AGRI	77	17	12.04	3	102	14	19.1	1
2.MNQR	109	15	8.32	12	385	1	18.7	2
3.FOOD	133	7	7.01	14	76.4	15	8.49	12
4.TEXTL	112	14	4.67	17	105	13	6.95	14
5.OTMF	132	9	6.72	15	182	8	8.16	13
6.PSHW	136	5	9.59	6	308	3	14.05	6
7.CGPR	171	2	13.96	2	354	2	14.6	5
8.CHEM	121	11	9.51	9	228	4	13.32	8
9.BMNM	153	3	10.11	5	150	9	6.74	15
10.METAL	135	6	9.53	8	218	5	10.27	9
11.MACH	133	8	9.57	7	149	10	9.15	11
12.CONNS	199	1	14.72	1	14.6	17	0.86	17
13.TRANTEL	113	13	8.61	11	216	6	15.4	3
14.COMCT	115	12	10.54	4	144	11	15.15	4
15.PURS	127	10	8.87	10	142	12	9.21	10
16.BANKI	86	16	6.37	16	206	7	13.71	7
17.OTSV	138	4	8.14	13	28.2	16	1.7	16

The 17 PRC industries constituting the official I/O model are indicated on the far left hand column of Table 1. These RBLs are calculated by setting the rows of each industry  $j$  in sequence to zero and then recalculating the output of all industries (including  $i = j$ ). The resulting outputs are denoted as  $X(-j)$  in the following paragraphs. The resulting RBL's in the unweighted case are calculated according to equation(2) while RBL\* in the weighted case is derived from the application of equation (9). Both RBLs and RBL\*s are expressed as percentages. The ranking of industry sectors shown on table 1 is arranged in declining order of magnitude of the RBL and RBL\* percentage.

The Construction (CONS) industry stands out on Table 1 as a key backward linkage

<sup>2</sup> RBL percentages in this column are rounded up to the nearest whole number.



industry sector. It shows the largest relative backward linkage in both the unweighted and weighted cases. The energy industry classification (CGPR) is ranked second in terms of the magnitude of both the unweighted (RBL) and weighted (RBL\*). Building materials and non-metallic minerals (BMNM) is another key sector in terms of backward linkages ranking third in the unweighted case and fifth in the case of the weighted model. There are several other industry sectors which are above average contributors to the backward linkage structure of the Chinese economy in both the weighted and unweighted cases: included in this category are the Power Steam and the Water industries (PSHW) ranked fifth and six in the unweighted (U) and weighted(W) categories respectively; Metal Production(METAL) which ranks sixth (U)and eighth(W) and Machinery and Equipment which is ranked eight (U) and seventh(W).

There are several industries which have weaker relative backward linkages in both the U and W cases. These include Mining and Quarrying (MNQR) ranked fifteenth(U) and twelfth(W);Textiles(TEXTL) ranked fourteenth (U) and seventeenth (W); the Chemicals medicines and chemical materials(CHEM) ranked eleventh (U) and ninth(W); transport and telecommunications (TRANTEL) ranked thirteenth (U) and eleventh (W); Public Utilities and Resident services, which ranks tenth on both U and W scales and the Banking and finance sector (BANKI) which is placed sixteenth on both scales.

There are a number of industries where the weights applied to the final demand do make a substantial difference to the rankings of backward linkage effects. Agriculture, Forestry and Fishing (AGRI)is the outstanding instance. This sector accounted for 24 percent of the PRC's GDP (total value added) in 1998. When no allowance is made for this fact(model 1) then the RBL for Agriculture is ranked at the bottom of the RBL rankings(seventeenth). However, if Agriculture's contribution to China's GDP is taken into account, the Agricultural sector has the third largest RBL\* behind the Construction (CONST) and energy (CGPR) sectors of the Chinese economy. There are four other sectors whose

rankings alter markedly when individual industry contributions to the PRC economy are accommodated. These are the other services sector (OTSV) where its fourth RBL ranking drops to thirteenth on the RBL\* rank; the Commerce and Catering trade sector which rises from twelfth (RBL) to fourth(RBL\*), the paper production sector (OTMF) which falls from ninth (RBL) to fifteenth (RBL\*) and the Food and Beverage sector ranked seventh (RBL) to fourteenth (RBL\*).

Backward linkages reveal the extent of backward dependence and industries with comparatively large backward linkages are key industries in the sense that they will purchase a significant proportion of the outputs of other industries. Several of the sectors identified as having weak backward linkages may still be important in a different context, namely, their contribution to forward sales. By their very nature, some industries will sell their output forward in preference to buying inputs. There is no final picture of the significance of individual industries in an I/O structure until the PRC's forward linkages are analysed.

This is particularly true of the Mining and quarrying(MNQR sector) which is clearly one of the key forward linkage industries in the PRC ranked first on the RFL classification and second in the weighted (RFL\*) case. Agriculture is not a highly ranked forward linkage industry on the RFL scale, but is the most significant forward seller when ranked on the weighted scale. In addition to these two primary industries, the two energy sectors: PSHW and CGPR are important input sources(forward sectors) to other industries in the input chain. PSHW is ranked third on the RFL scale and sixth on the weighted RFL\* scale while CGPR is ranked second and fifth respectively on the unweighted (RFL) and unweighted (RFL\*) respectively. The transport and Telecommunication sector (TRANTEL) is also an important forwarding industry in the PRC economy as it is ranked sixth and third respectively on the unweighted and weighted forward linkage scales. Some other sectors resemble Agriculture by providing evidence of key forward linkages on one but not both RFL and RFL\* scales. This

applies to Chemicals, Medicines and associated supplies (CHEM) which is the fourth ranked contributor to the PRC's forward linkages on the unweighted scale(RFL); to the Metals industries (METAL) ranked fifth in the RFL classification and the Commerce and Catering Trade which ranks 4<sup>th</sup> on the RFL scale.

## **5. The PRC's Key Industry Linkage Sectors.**

The value of identifying the key industry linkages is to emphasise the role that such industries play in the development of the domestic economy. Identification of these key linkage sectors informs domestic policy directed towards economic development in the country concerned. The analysis of absolute backward and forward linkages will also indicate how the outputs of the key industries are distributed backward and forward to others in the domestic economy. So development policies focussed upon one of the key industry sectors will have impacts on the remaining industries which can be observed by the policy maker.

The caveat which must be entered here is that linkage analyses based on I/O tables have quite tight limits in relation to the definition of "keyness", or importance. A linkage analysis does not provide the full picture about the importance of the export oriented industries, for example, which are subject to the vagaries of international markets. Textile, Leather and fur products (TEXTL) is the leading example in this study. It does not feature as an industry with strong forward or backward linkages and yet we know that it is a most significant component of the PRC's export basis. It is a victim of the very broad classification represented by the TEXTL sector which includes raw material inputs to the textile production process and as a consequence does not appear to have strong backward linkage and sells a significant proportion of its output to foreign markets weakening its case to claim some status as a key forward linkage industry. However, the overall case for studying linkages remains, although it is wise to keep the above mentioned caveats in mind.

**Table 2: Top 6 Rankings of PRC industries:  
Strength of Backward and Forward Linkages**

Relative Backward		Relative Forward		Both <sup>3</sup> : RBL and RFL	
Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
CONST	CONST	MNQR	AGRI	CGPR	CGPR
CGPR	CGPR	CGPR	MNQR	PSHW	AGRI
BMNM	AGRI	PSHW	TRANTEL	METAL	COMCT
OTSV	COMCT	CHEM	COMCT		PSHW
PSHW	BMNM	METAL	CGPR		
METAL	PSHW	TRANTEL	PSHW		

The six top ranked industries in relation to both relative backward and forward linkages are identified on Table 2. This table also indicates those industries which feature as key sectors (top six) in both relative backward and forward linkages.

The industries with the six strongest relative backward linkages are shown on Table 2 for the two models developed in this study, namely, the unweighted case (Model 1) and for the alternative (Model 2) where the proportion of industry value added to GDP is used to weight final demand and primary inputs.

In relation to backward linkages, the following four industries appear among the six strongest backward linkage industries in both the weighted and unweighted cases. These are the construction sector (CONST), the two energy sectors (CGPR and PSHW) and the building materials and non-metallic minerals (BMNM) sectors. The Agriculture sector (AGRI) is ranked among the top six backward linkage sectors in the weighted but not in the unweighted case, while the other Service sector( OTSV) is a strong backward linkage sector in the unweighted (model 1) only.

The key forward linkage industries are Mining and Quarrying (MNQR), the energy sectors (CGPR and PSHW), and Transport and Telecommunications (TRANTEL). These four sectors are included among the six strongest forward linkage sectors in both the

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<sup>3</sup> Both indicates those industries ranked in the top 6 Chinese industries in relation to the unweighted model 1 and weighted model 2.

unweighted and weighted cases. Further Agriculture (AGRI) remains the strongest forward linkage sector when its large value added contribution to China's GDP is recognised. The Commerce and Catering (COMCT) sector is ranked fourth as a forward linkage industry in the weighted case, while Chemicals medicines and related supplies (CHEM) and the Metal sector (METAL) are China's fourth and fifth most significant forward linkage industries in the unweighted model 1 case.

Those industries which are ranked as both strong backward and forward linkage sectors are of particular interest for developing economies such as the PRC. The growth of these will stimulate the development of linked industries in both a backward and forward direction. Those sectors prominent in their contributions to both backward and forward linkages are included in the last two columns of Table 2 which are labelled "Both". In the unweighted case (model 1) the two energy sectors (CGPR and PSHW) and the Metal industries appear as industry possessing strong backward and forward linkages. Again the two energy sectors are prominent as strong backward and forward linkages industries in the weighted model 2. Agriculture (AGRI) and COMCT are also key backward /forward sectors in the weighted but the not the unweighted case.

## **6. Conclusion**

Backward linkages measure the degree of dependence of industrial sectors on the supply of inputs from other sectors while forward linkages relate to interdependence secured through the sale of one industry's output to others as inputs. The policy significance of identifying the key or most important backward and forward linkages is that policy makers can determine the impact flowing from the stimulation of a key sector on other sectors of the economy. Linkages can be measured in absolute or relative terms by extracting relevant industry rows and columns from the I/O matrix and noting the impact of this withdrawal on

the outputs of the remaining industries. The advantage of measuring linkages in relative form is that industries can be ranked in terms of their linkage impacts. A criticism of previous extraction studies is that such methods ignore the relative value added of each industry to GDP. To eschew this problem, two versions of the extraction method were applied here: the first was the conventional unweighted method (model 1) but the second was the weighted version (model 2) where the weights were the ratio of industry value added to GDP for each of the seventeen industries on the PRC I/O table.

The results show that in all four cases: relative backward, relative forward, weighted and unweighted, the two energy sectors: Power, Steam and Hot water (PSHW) and Coking Gas and Petroleum refining (CGPR) rank as key sectors of the economy. Further, the Metal Products industry (METAL) ranks as an important backward and forward linkage industry in the unweighted case, while the Agricultural sector (AGRI) also features as a key bidirectional industry in the weighted case alone and indeed AGRI is the most important sector in relation to RFL. Other major backward linkage sectors include the construction sector, other services, Building materials and non-metallic , minerals and the commerce and catering sectors, while other key forward linkage industries include Mining/Quarrying, Transport and Telecommunications Chemicals and medical supplies.

An overall summary view of the PRC's current status is directed through an answer to the question posed in the introduction to this paper: how mature is the Chinese economy and what are the prospects for a return to pre 1997-1998 growth rates? Agriculture (AGRI) remains a key linkage sector and the expansion of its output will stimulate other industries but Agriculture has been joined by other key sectors in particular the energy sector, the commerce and catering trade industry and the metal products industry which provide strong bidirectional links. The PRC has certainly moved on from a traditional economy reliant

predominantly on agriculture, further, a sufficiently diverse interindustry linkage structure is capable of returning the Chinese economy to rapid growth.

These conclusions, which relate to the whole PRC economy may differ in regions of China. The PRC's recent growth has been concentrated along its coast while its inner development in the Central and Western provinces of the country appear to be slower, clearly, this regional pattern warrants a separate analysis, which will be addressed in a further study.

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