Industrial and Aggregate Measures of Productivity Growth in China, 1982-2000

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Abstract

We estimate productivity growth at the industry level of the entire Chinese economy using a time series of input-output tables covering 1982-2000. Capital input is measured using detailed investment data by asset and labor input uses demographic information from household surveys. We then show how these industry growth accounts may be consistently aggregated to deliver a decomposition of aggregate GDP. We find a wide range of productivity performance at the industry level. Aggregate TFP growth was rapid in the early 1980s, but negligible during 1994-2000. The main source of growth during the 1982-2000 period was capital accumulation, with a small negative contribution from the reallocation of factors across industries.

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I. Introduction

While it is widely agreed that the Chinese economy has grown rapidly since the reforms started in 1978, there is disagreement about both the magnitude and sources of that growth. Was the dominant factor the accumulation of capital, total factor productivity growth, or the restructuring of the economy from agriculture to manufacturing and services? A question related to the structural transformation of the economy is how estimates of aggregate GDP growth may be reconciled with the estimates at the industry level. These questions are difficult to answer given the quality and quantity of data available. The answers to them, however, are important in understanding the effects of past economic policies and hence to devise future policies.

This paper estimates the sources of growth of industry output – the growth capital, labor and intermediate inputs, and total factor productivity. To do this we introduce newly developed data, including a time series of input-output tables and estimates from a survey of the labor force. Our measures account for the changing composition of the labor force and investment. The second aim of the paper is to discuss how these industry measures may be aggregated to GDP. We describe three aggregation approaches to highlight the methodological issues of separating out the roles of factor accumulation, factor reallocation and sectoral total factor productivity growth. They are: (i) aggregate production function, (ii) aggregate production possibility frontier (PPF), and (iii) direct Domar-weighted aggregation. The first approach may be familiar to many readers; the aggregate PPF method relaxes the strict assumptions that approach and allows us to identify the effects of reallocating value-added across industries. The third method allows us to distinguish between factor accumulation and reallocation of factors.

The final aim of the paper is to discuss the various approximations and assumptions that are necessary to construct time series of output and inputs at the industry level that are internally consistent. We hope to lay the groundwork for a systematic and clear framework for sectoral productivity analysis of China, i.e. to sketch out a comprehensive approach, and to point out the missing elements for further research to produce better estimates of growth and productivity change.

We divide our sample into four sub-periods based on the major breaks in economic reform policies. (1) 1982-84, when growth is mainly attributed to the efficiency gains in the agriculture sector after the rural reforms began in 1978 when the "household registration system" was launched[1]. (2) 1984-1988 is the period of reform of state-owned enterprises when they were given greater autonomy in deciding production and prices. The "contract responsibility system" was introduced in 1987 (Chow, 2002, pp50). The two-tier "plan and market" structure was also introduced, where each commodity carried a planned price set by the central government, and an unregulated market price. Thus, for this period, growth is widely attributed to the industrial sector reforms. In addition, the government also scaled up the original "open door policy" in 1984, and developed fourteen cities as "coastal open cities", in addition to the original four coastal cities (Shenzhen, Zhuhai, Shantou, and Xiamen), to attract further foreign investment and technology transfers. (3) 1988-1994, when the government adopted a new "socialist market economy" doctrine and many more "special development zones" were

[1] Lin, Cai and Li (2002, pp.262) note that by 1984, almost all the peasants were in the registration system, and rural income per capita had grown by 14.5% per year between 1980-1984.

established[2]. (4) 1994-2000 was a period when the role of State Owned Enterprises was weakened and private ownership was elevated as an "important component of the economy". In addition, tariffs were gradually reduced to be ready for accession to the World Trade Organization.

We estimate aggregate TFP growth at2.5% per year for the whole period, 1982-2000. However, this has been decelerating rapidly, from 9.1% during 1982-84 to 3.3% (1984-88) to 2.6% (1988-94), and even turned negative for 1994-2000 (-0.3%). This deceleration occurred in the secondary and tertiary industries, only in Agriculture was there a good TFP growth performance during 1994-2000. This average hides a wide range of performance at the sector level; for the 1982-2000 period, TFP growth ranged from 5.6% for Electrical Machinery to -10% for Oil & Gas Mining.

Our three aggregation methods identify the industry role more precisely. Using the aggregate production function approach, aggregate TFP growth is estimated at 1.9%, however, the production possibility frontier method puts it at 2.5%, the difference being the reallocation of value added. Of the 2.5% aggregate growth, TFP growth at the industry level contributes 2.70 percentage points while the reallocation of capital -0.17 points and the reallocation of labor -0.02 points.

The data used in this paper grew out of the International Comparison of Productivity among Pan-Pacific Countries (Asian Countries) (ICPA) project sponsored by the Japanese RIETI (Jorgenson, et. al. 2007). The methodology described here for the construction of industry output and inputs is also that used in the project.

[2] The Tiananmen incident occurred in 1989 and growth was interrupted, however, by the end of 1992 China had resumed its rapid growth path (Chow, 2002; pp61). After his famous visit to Shenzhen in 1992, the Chinese leader, Deng Xiaoping, reaffirmed and pushed economic liberalization.

This paper is organized as follows. We start with an overview of the literature on estimating TFP growth for China in sector II. In sector III we present our methodology for industry productivity and aggregation. Sector IV discusses the construction of output and input indices for sector. Sector V and VI present the results of industrial level, aggregate TFP and reallocation effects. Section VII concludes.

II. **Literature Review**

There are a number of productivity studies of China at the aggregate level, or using value added for broad (1-digit) industries. There are fewer industry studies focusing on the 2-digit level, and even fewer discussing the aggregation across industries. There is a serious debate in this literature about the magnitude of aggregate TFP growth, and a parallel debate about the future trend of TFP growth.

Chow (1993), using official data prior to 1980 that only included the material sectors (i.e. not including the service sectors that were estimated later), concluded that there was essentially no technical progress in the 1952-80 period. Chow and Li (2002) follow Chow (1993) by estimating a Cobb-Douglas production function, but update the analysis to 1998. They find a positive TFP growth of 3.03% in the post-reform period, together with 5.1% growth in capital input and 1.2% growth in labor input to explain the 9.4% overall GDP growth from 1978 to 1998. They also simulate an increasing trend of TFP till 2010.

Borensztein and Ostry (1996) get a somewhat similar result, they estimate that TFP growth was -0.7% per year during 1953-1978, but rose to an average 3.8% per year during 1979-1994. Fan, Zhang and Robinson (1999) share a similar optimistic view of economic growth in China. They divide the Chinese economy in four sectors: agriculture, urban industrial, urban services, and rural enterprises for 1978-95 and estimate that TFP growth contributed 4.2 percentage points to the aggregate annual GDP growth. Hu and Khan (1997) also estimate China's TFP growth at 3.9 percent during 1979-1994, this is more than 50 percent of output growth, while capital formation contributed 33 percent.

However, many other studies reached a much more pessimistic view of productivity performance. Woo (1998) estimates GDP growth using value added from the primary, secondary and tertiary sectors, and decomposed it into factor growth, reallocation and TFP growth. Instead of using the official real value added data, he recalculates them using producer price indices. The result is that, for the period 1979-93, he revised the official growth rate from 9.3% per annum to 8.0%, which is then decomposed to capital accumulation (4.9%), labor force growth (1.4%, with no adjustment for changes in labor composition), reallocation effect (0.6%) and TFP growth (1.1%). He also reports that the TFP growth rate ranges from 2.76 to 3.76% per year for the period 1979-84, but only -0.11 to 1.58% per year for 1984-93, that is, a decline from the initial years of the reform to the later years. In another study that does not use the official GDP data, Ren (1997) estimates GDP growth at 6.0% during 1986-1994, instead of the official 9.8%That paper does not discuss productivity measurement, but is focused primarily on measurements of real GDP raising data issues that are relevant to our discussions here.

In more recent papers, Young (2003) and Maddison and Wu (2006) also share the same view as Woo (1998) and Ren (1997). They argue that since officials are rewarded for superior performance and punished for failing to meet GDP growth target, local officials tend to overstate the growth of output. Their adjustments to GDP growth is shown in Figure 1. Maddison and Wu's GDP growth (dotted line) is below the official NBS growth (bold line) for all years except 1995. They estimated that GDP growth is about 8.7% for 1992-2003, compared to the official 9.4% (plotted as the line with square). Young (2003, plotted with dashed line) made only small adjustments for the period 1980-1986, but substantially lowered GDP growth for 1987-98, he even estimated negative growth for 1989.

Young (2003) discusses the problems with the official estimates of real GDP and uses the alternative deflators that Ren (1995) suggested for the primary, secondary, and tertiary sectors[3]. He makes an adjustment for the changing compositioin of the labor force and estimates that non-agricultural TFP growth was only 1.4% per year compared to the 3.0% using official numbers for 1978-98. He, however, also points out that ignoring agriculture makes this a misleading estimate, that sector is large (a quarter of GDP in this period) but with rather poor data on inputs (labor, land and capital). He comments that China's post-reform productivity performance of nonagricultural economy is respectable but not outstanding, and concludes that the efficiency gains lie mainly in the agriculture sector.

Place figure 1 here.

On theother hand, Perkins and Rawski (2008) accepts the official GDP estimates after 1995 (the revised NBS line in figure 1), and only slightly revise the growth rate down by less than 1% for the period before 1995. They estimateaggregate TFP growth at 3.8 percent between 1978 and 2005 and suggest that TFP accounts for 40% of overall growth of nearly three decades after economic reform.

[3] Young notes that using alternative deflators brings the growth of output per capita from 7.8% down to 6.1% for the aggregate, and from 6.1% to 3.6% for the nonagricultural sector.

Ren and Sun (2005) constructed a time series of input-output accounts for 1981-2000, and calculated the TFP growth of all the 2-digit level sectors. They calculated a Domar-weighted aggregate measure for 4 sub-periods and find a fast TFP growth for 1981-1984, then a steady TFP growth at 3.1% for 1984-1988 and 3.8% for 1988-1994, and finally, a slow 0.52% for 1994-2000. Like Ren and Sun, Wang and Yao (2001) also take into account labor quality distinguishing workers by the number of schooling years. Using various assumptions about labor income shares, they estimate TFP growth to be in the -0.87 to -0.38% per year range for the pre-reform period, and in the 1.92 to 2.98 range for 1978-1999. That is, the TFP estimates in both Ren and Sun (2005), and Wang and Yao (2001) are somewhere between the low estimates of 1.1 – 1.4% of Woo and Young, and very high estimates of 4% of Hu and Khan.

There are also a number of other studies using firm level data rather than economy aggregates, including Jefferson, Rawski and Zheng (1996, 2000), Groves, Hong, McMillan and Naughton (1994), and Woo, Hai, Jin and Fan (1994). These studies seem to agree that collective owned enterprises showed much higher TFP growth than state owned ones, but gave very different estimates of the actual performance of the state owned enterprises, ranging from positive to negative.[4] While our analysis at the 2-digit level cannot be compared to these enterprise level studies, we should note that our results also show both positive and negative productivity growth.

III. Methodology

Our preferred approach to estimating industry productivity growth is to use gross output data rather than the more readily available value added that is used in many of the

[4] Some of these differences are discussed in Woo (1998), which also surveyed other papers.

above studies. We use input-output accounts which force the analysis to be consistent across the whole economy, a revision of the output deflator of one sector not only changes the output and productivity growth of that sector, but also changes the real input into some other sector. For example, the service sectors are poorly measured in all countries and especially so in China. Services are also inputs into the manufacturing sector. The IO approach forces us to explicitly confront this issue of poor input measurement for estimating the TFP in manufacturing. We emphasize this since industry level studies have focused on the manufacturing sector.

We summarize our methodology here, this is described in detail in our accounting of U.S. economic growth in Jorgenson, Ho and Stiroh (2005). The economy is divided into 33 sectors producing 33 different commodities. Each sector of the economy is described by a production function which uses primary factors and intermediate inputs to produce gross output. This output is used for final demand and intermediate demand, and GDP is the aggregate of final demand. Nominal GDP is also the sum of sectoral value added.

1. Industrial Growth Accounting

The gross output of sector *j* in period *t* is assumed to be produced with a Hicks-neutral production function using various types of capital, labor and intermediate commodities:

(1) $$Y_{jt} = A_{jt} f(K_{1jt},..K_{kjt}, L_{1jt},..L_{ljt}, Z_{1jt},..Z_{njt})$$

The index of productivity is represented by A_{jt}. We assume that the function is separable in such a way that the various types of capital, labor and intermediate inputs may be aggregated into indices K_{jt}, L_{jt}, and Z_{jt} respectively, so we may write the production function as:

$$(2) \qquad Y_{jt} = A_{jt} f(K_{jt}, L_{jt}, Z_{jt})$$

Industry capital input is derived by aggregating over three types of assets – structures (and land), motor vehicles, and all other equipment – using rental prices as weights. Eq. 31 below shows how K_{kjt}, k=1,2,3 are aggregated to K_{jt}. Labor input is an aggregate of the number of workers cross classified by sex, age, and educational attainment (L_{ljt}) using wages as weights (eq. 34 below). The material input index is aggregated over the 33 commodities. These intermediate goods are produced by the 33 sectors plus imports. The construction of these input aggregates is described in section IV below.

We assume that (2) is described by a translog form:

$$(3) \qquad d\ln Y_{jt} = \bar{v}_{Kjt} d\ln K_{jt} + \bar{v}_{Ljt} d\ln L_{jt} + \bar{v}_{Zjt} d\ln Z_{jt} + d\ln A_{jt}$$

where $d\ln Y_{jt} = \ln Y_{jt} - \ln Y_{jt-1}$ denotes the growth rate, and the $\bar{v}$ weights are averaged shares of the subscripted input in nominal gross output :

$$(4) \qquad \bar{v}_{Kjt} = \tfrac{1}{2}(v_{Kjt} + v_{Kjt-1}) \quad \text{etc.}$$

$$v_{Kjt} = \frac{P_{Kjt} K_{jt}}{P_{Yjt} Y_{jt}}$$

$$v_{Ljt} = \frac{P_{Ljt} L_{jt}}{P_{Yjt} Y_{jt}}$$

$$v_{Zjt} = \frac{P_{Zjt} Z_{jt}}{P_{Yjt} Y_{jt}}$$

The P's denote the prices, P_{Yjt} is the output price to the producer (ex-factory price less taxes), P_{Kjt} is the rental price of capital, and P_{Ljt} is the price of labor input. The value of capital input is defined residually such that the value of total inputs equals the value of ouput:

(5) $$P_{Yjt} Y_{jt} = P_{Kjt} K_{jt} + P_{Ljt} L_{jt} + P_{Zjt} Z_{jt}$$

Purchasers buy output at the industry price, P_{Ijt}. The difference between the two valuations is the net taxes on production, NT:

(6) $$P_{Ijt} Y_{jt} = P_{Yjt} Y_{jt} + NT_{jt}$$

For aggregation to GDP we need a concept of industry valued-added. The real value added of sector j, V_{jt}, is defined by writing output as a weighted share of value added and intermediate input:

(7) $$d \ln Y_{jt} = \bar{v}_{Vjt} d \ln V_{jt} + \bar{v}_{Zjt} d \ln Z_{jt}$$

The following is then implied from eq. (3) for the growth of value added:

(8) $$\bar{v}_{Vjt} d \ln V_{jt} = \bar{v}_{Kjt} d \ln K_{jt} + \bar{v}_{Ljt} d \ln L_{jt} + d \ln A_{jt}$$

where $v_{Vjt} = \dfrac{P_{Kjt} K_{jt} + P_{Ljt} L_{jt}}{P_{Yjt} Y_{jt}}$

is the share of value added in gross output. The price of value added is then given by the nominal value of capital and labor input divided by the quantity index:

(9) $$P_{Vjt} = \frac{P_{Kjt} K_{jt} + P_{Ljt} L_{jt}}{V_{jt}}$$

2. Aggregate Growth Accounting

The above describes the accounting for each sector. We now turn to the aggregation over all the sectors to derive national output. We present three alternative methodologies to construct economy-wide measures of output growth: aggregate production function, aggregate production possibility frontier, and direct aggregation across industries,. The first requires the strongest assumptions about factor mobility and identical value-added functions, while the second does not require that value-added prices to be identical across industries. The third approach relaxes all the restrictions on value-added functions. We give a summary description here, the details are given in Jorgenson, Ho and Stiroh (2005, section 8.2).

1) Aggregate Production Function

The aggregate production function is the simplest approach and used in many of the studies discussed in section II. Four assumptions are required for the existence of such a function: (i) the industry gross output function is separable in value added, (ii) the value-added function is the same across industries (up to a scalar multiple), (iii) the functions that aggregate over capital types and labor types is identical in all industries, (iv) each type of capital and labor receive the same price in all industries. These assumptions mean that the price of industry value-added is the same across industries:

(10) $$P_V^{PF} = P_{V,j}$$

where the common price, P_V^{PF}, is the price of value-added for the aggregate production function. Aggregate real value added is then the simple sum of sector value added:

(11) $$V_t^{PF} = \sum_j V_{jt}$$

Under the assumption of common capital and labor prices, the aggregate quantity of capital input from asset type *k* and labor input type *l* is simply the sum over industry inputs:

(12) $$K_{kt} = \sum_{j} K_{kjt} \quad \text{and} \quad L_{lt} = \sum_{j} L_{jlt}$$

Aggregate capital services (K_t) and labor input (L_t) are defined as translog aggregates of these different types of capital and labor:

(13) $$d\ln K_t = \sum_{k} \bar{v}_{Kkt} d\ln K_{kt} \qquad \text{and } d\ln L_t = \sum_{l} \bar{v}_{Llt} d\ln L_{lt}$$

where v_{Kkt} is the share of type *k* capital input in total capital input, and v_{Llt} is the share of type *l* labor input in total labor input. The prices of aggregate capital input and labor input are then given by the nominal values divided by these quantity indices:

(14) $$P_{Kt} = \sum_{k} P_{Kkt} K_{kt} / K_t \quad \text{and } P_{Lt} = \sum_{l} P_{Llt} L_{lt} / L_t$$

With the above we can write the aggregate production function as:

(15) $$V_t^{PF} = f(K_t, L_t, t),$$

and the corresponding nominal identity for GDP at factor cost, i.e. before indirect taxes:

(16) $$P_V^{PF} V^{PF} = P_{Kt} K_t + P_{Lt} L_t$$

We can now define aggregate TFP growth from the aggregate production function as:

(17) $$d\ln A_t^{PF} = d\ln V_t^{PF} - \bar{v}_{Kt} d\ln K_t - \bar{v}_{Lt} d\ln L_t$$

where $v_{Kt} = \dfrac{P_{Kt} K_t}{P_{Kt} K_t + P_{Lt} L_t}$ and $v_{Lt} = \dfrac{P_{Lt} L_t}{P_{Kt} K_t + P_{Lt} L_t}$.

2) Aggregate Production Possibility Frontier

A less restrictive approach is the production possibility frontier used in Jorgenson and Stiroh (2000). Here we relax the assumption that industries have identical value-added functions which allowed us to write aggregate output a simple sum in eq. (11) above. We now define aggregate value-added as a Divisia index of industry value added:

(18) $$d\ln V = \sum_j \bar{w}_j d\ln V_j$$

where $\bar{w}_j$ is the average share of industry value-added in aggregate value-added:

(19) $$\bar{w}_j = \tfrac{1}{2}(w_{jt} + w_{jt-1}) \qquad w_j = \frac{P_{Vj}V_j}{\sum_j P_{Vj}V}$$

Note that V here denotes value-added from the production possibility frontier while V^{PF} denotes that from the aggregate production function.

We maintain the same assumptions for capital and labor input so that aggregate capital and labor are as given in equation (12) above. Aggregate value-added is then written as $V = f(K, L, t)$. We define TFP growth from the aggregate production possibility frontier in the same manner as equation (17) above:

(20) $$d\ln A_t = d\ln V_t - \bar{v}_{Kt} d\ln K_t - \bar{v}_{Lt} d\ln L_t$$

3) Direct Aggregation Across Industries

The third approach for measuring the sources of growth for the aggregate economy is direct aggregation across industries, a method developed by Jorgenson, Gollop, and Fraumeni (1987, Chapter 2) using the idea in Domar (1961). Here we need only assume that the value-added function exists for each industry, but impose no restrictions on prices of value-added or factor inputs. This approach allows us to trace the origins of aggregate growth and factor accumulation to the underlying industry sources.

Aggregate output is as defined by the production possibility frontier in eq. (18) above. Substituting in the industry value-added from eq. (8) we obtain aggregate growth as the weighted contributions of industry capital, labor and TFP:

$$\text{(21)}\qquad \begin{aligned} d\ln V_t &= \sum_j \bar{w}_{jt} d\ln V_{jt} \\ &= \sum_j \bar{w}_{jt} \frac{\bar{v}_{Kjt}}{\bar{v}_{Vjt}} d\ln K_{jt} + \bar{w}_{jt} \frac{\bar{v}_{Ljt}}{\bar{v}_{Vjt}} d\ln L_{jt} + \bar{w}_{jt} \frac{1}{\bar{v}_{Vjt}} d\ln A_{jt} \end{aligned}$$

The weights on industry TFP involve two proportions, w_j is j's share of aggregate value added, and v_{Vj} is the share of value-added in industry j's output. In terms of period t's values, this simplifies to the following, before averaging:

$$\text{(22)}\qquad \frac{w_{jt}}{v_{Vjt}} = \frac{P_{Yjt} Y_{jt}}{\sum_i P_{Vit} V_{it}}$$

This ratio of industry output to nominal aggregate output is the usual interpretation of the Domar weight (Hulten, 1978). Eq. (21) employs a two-period average version of it. Note that the sum of the Domar weights is more than one reflecting how industry TFP have two effects, the direct effect on industry output, and an indirect effect via intermediate flows.

Aggregate TFP growth from the production possibility frontier may now be re-written by substituting (21) into (20):

$$\text{(23)}\qquad \begin{aligned} d\ln A_t &= \sum_j \bar{w}_{jt} \frac{1}{\bar{v}_{Vjt}} d\ln A_{jt} \\ &\quad + \left(\sum_j \bar{w}_{jt} \frac{\bar{v}_{Kjt}}{\bar{v}_{Vjt}} d\ln K_{jt} - \bar{v}_{Kt} d\ln K_t \right) + \left(\sum_j \bar{w}_{jt} \frac{\bar{v}_{Ljt}}{\bar{v}_{Vjt}} d\ln L_{jt} - \bar{v}_{Lt} d\ln L_t \right) \\ &\equiv \sum_j \frac{\bar{w}_{jt}}{\bar{v}_{Vjt}} d\ln A_{jt} + R_t^K + R_t^L \end{aligned}$$

This equation shows how the growth of aggregate TFP from the PPF comes from three sources. The first is a Domar-weighted sum of industry TFP growth. The second and third sources reflect the reallocation of factors. These reallocation terms quantify the departure from the assumption of equal input prices in contructing the aggregate measures for K_t and L_t. A positive reallocation term happens when industries with higher capital input prices have faster input growth rates.

We can also quantify the effect of the assumptions required for the existence of the aggregate production function. Recall that the PPF relaxes the assumption of equal value-added prices used for the aggregate production function. We define the reallocation of value-added as the difference in the growth rates of the two definitions of aggregate output:

(24) $$R_t^{VA} = d\ln V_t^{PF} - d\ln V_t = d\ln V_t^{PF} - \sum_j \bar{w}_{jt} \ln V_{jt}$$

Another way of seeing this is to begin from eq. (17) for the growth of TFP from the aggregate production function and combining with (20):

(25) $$\begin{aligned} d\ln A_t^{PF} &= d\ln V_t^{PF} - d\ln V_t + d\ln A_t \\ &= d\ln V_t^{PF} - d\ln V_t + \sum_j \bar{w}_{jt} \frac{1}{\bar{v}_{Vjt}} d\ln A_{jt} + R_t^K + R_t^L \\ &= \sum_j \bar{w}_{jt} \frac{1}{\bar{v}_{Vjt}} d\ln A_{jt} + R_t^{VA} + R_t^K + R_t^L \end{aligned}$$

This says that TFP growth from the aggregate production function is the Domar-weighted sum of industry TFP growth, the reallocation of value-added due to the assumption of equal value-added prices, and the reallocation of capital and labor due to the assumption of equal factor prices.

IV. Constructing output and input indices for sectors

Equation (4) describes industry gross output as a function of capital, labor, intermediate inputs and technology, which is indexed by time, *t*. In implementing the system we further divide intermediate input into aggregate energy input and non-energy material input. We now briefly describe the construction of these industry inputs and outputs, the details are given in Ren and Sun (2005). They are based on a time series of input-output "Use" or "Activity" tables which consist of the inter-industry section, the value added section, and the final demand section. These tables covering 1981-2000 were constructed in collaboration with the National Bureau of Statistics of China and researchers from the BeiHang University[5].

The original data set consist of 33 sectors. Here we concentrate on 26 sectors in Secondary Industry, and the total Primary and Tertiary industry. Column *j* of the Use matrix gives the value of each intermediate input, $U_{ij} = P_i^Z Z_{ij}, \quad i = 1,...n = 33$, and the value of capital input ($P_{Kj} K_j$) and labor input ($P_{Lj} L_j$). The net taxes that are attributable to capital are included in capital input. The column sum gives us the value of gross output as described in (5) and (6) above:

$$(26) \qquad P_{Ijt} Y_{jt} = P_{Kjt} K_{jt} + P_{Ljt} L_{jt} + \sum_i P_{it}^Z Z_{ijt}$$

In Table 1, the values for gross output, capital input, labor input, energy aggregate input, and non-energy material aggregate input, capita stock and employment are given for 2000. The sum of the capital and labor value added columns equals GDP for 2000.

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[5] The staff from the National Accounts Department include Xu Xianchun, Qi Shuchang, Liu Liping, Dong Lihua and Zhao Tonglu. Those from BeiHang University are TLi Xiaoqin, Ma Xiangqian and Ren Ruoen.

(a) Output and Intermediate input.

The NBS used the Material Product System (MPS) for the I-O tables before 1987 and transformed gradually to the System of National Accounts (SNA) after 1987. Our time-series were constructed in the following manner to deal with this and other changes. 1) Aggregate series for the nominal value of total input, total value-added, and final use were compiled for 1981-2000. 2) Four nominal benchmark Use tables for 1981, 1987, 1992 and 1997 were constructed. Due to differences in accounting systems, industrial classification, statistical coverage and definitions, all the tables were adjusted to conform to the 1997 benchmark conventions. The tables are scaled to match the latest GDP series that is consistent with the 1997 benchmark. Since the original 1981 table is based on the MPS, the nominal value table for 1981 was constructed using the structure of the 1987 table and estimates of the changes in technical parameters between 1981-1987. 3) Based on these four comparable benchmark tables, the tme-series current price Use tables were interpolated for 1982-2000. This involve rebalancing the matrices so that the column totals match the industry output in step (1)[6].

Row *i* of the Use matrix gives us the intermediate use of commodity *i* by all the industries, and the purchases by final demanders (consumption, investment, government and net exports). The row sum gives us the value of the domestic output of *i*. Each commodity may be made by a few industries, and each industry may make a few commodities. The structure of commodity output is given by the "Make" matrix, cell V_{ji} gives the value of commodity *i* made by industry *j*. The prices of commodities ($P_i^Z, \quad i = 1,...n$) should ideally be derived by aggregating the price of domestic output

[6] This rebalancing uses the minimum sum of squared deviations approach used in the studies in Jorgenson, Kuroda and Motohashi (2008).

with the price of imports (or from surveys covering both items). However, since there is little data on import prices, here we assume that they behaved in the same way as domestic prices.[7] The price of commodities (P_{it}^{Z}) is derived from the prices of industry output (P_{Ij}) using the Make matrix.[8]

Commodity price indices for the 33 sectors were compiled using the approach used for the estimation of sectoral GDP at constant prices in OECD (2000). The industry price indices were converted from the commodity price indices using the 1981-2000 Make tables. This is described in detail in Xu et al. (2005).

These price indices are used to deflate the nominal industry output to give the quantity indices (Y_{jt}), and to deflate the intermediate inputs to give the quantities, Z_{ijt}. To do this we assume that all purchasers pay the same price for a given commodity. This is, of course, not very accurate in the period of controlled prices and favored sectors; however, improvements will have to wait for more detailed price data.

Given the price and quantity of input *i* for each sector *j* from the above steps, we define the intermediate input aggregate as a Divisia index of all the components:

$$(27) \qquad d\ln Z_{jt} = \sum_i \bar{v}_{ijt}^{Z} d\ln Z_{ijt}\,, \qquad v_{ijt}^{Z} = \frac{P_{it}^{Z} Z_{ijt}}{P_{Zjt} Z_{jt}}$$

where $P_{Zjt} Z_{jt} = \sum_i P_{it}^{Z} Z_{ijt}$ is the total value of intermediate inputs for sector *j* and P_{Zjt} is the price index for aggregate material input into *j*. These are the terms that enter into eqs. (3) and (4) in the calculation of the productivity index for *j*.

[7] Young (2003) used Hong Kong trade data to estimate an import price index for China. Expanding approximations like this could provide better estimates in the future.
[8] The details of relation between industries and commodities, and between domestic and imports, are given in Jorgenson, Ho and Stiroh (2005).

(b) Capital input.

The flow of capital services is derived by aggregating over three asset classes – structures, motor vehicles and all other equipment. Our method involves distinguishing between the stock of assets and the flow of services derived from them and is described in detail in Jorgenson, Ho and Stiroh (2005, Chapter 5). In this section, we summarize our adaptations to the Chinese data, and the detailed description is in Ren and Sun (2005). The main sources of investment data used are from the *China Statistical Yearbook on Investment in Fixed Assets* and the *China Statistical Yearbook* (various issues).

The stock of capital of type *k* in sector *j* (S_{kjt}) is accumulated from the flow of investment using the perpetual inventory method:

(28) $S_{kjt} = (1-\delta_k)S_{kjt-1} + I_{kjt}$, *k*=structures, equipment, motor vehicles

where I_{kjt} is the real investment in asset *k*, and δ_k is the geometric depreciation rate. The depreciation rates are approximated by assuming that the asset life for structures is 40 years, 16 years for equipment, and 8 years for motor vehicles. The asset life for structures is shorter than that used in most U.S. studies given the large differences in buildings between China and the U.S. The asset lives for equipment are taken from studies of capital stock in other countries. The depreciation rates used are 17% for equipment, 8% for structures and 26% for motor vehicles. Real investment is given by the data on value of investment divided by the price of capital goods:

(29) $I_{kjt} = VI_{kjt} / PI_{kt}$

The total stock of capital for sector j is the aggregate of the three types:

(30) $d\ln S_{jt} = \sum_k \bar{v}^S_{kjt} d\ln S_{kjt}$ $\qquad v^S_{kjt} = \dfrac{PI_{kt}S_{kjt}}{\sum_a PI_{at}S_{ajt}}$

Each of the asset types generate a flow of services in period t proportional to the stock that was in place at the end of t-1 ($K_{kjt} \propto S_{kjt-1}$), at a rental cost P_{Kkjt}. The taxation of capital income has undergone many changes in the 1990s and here we take a highly simplified view of it to express the rental cost (in contrast to the detailed description of the US tax code in Jorgenson, Gollop and Fraumeni 1987). We express the rental cost of one unit of the capital stock S_{kjt-1} used in period t in sector j as:

(31) $$P_{Kkjt} = [r_{jt} + (1+\pi_{kt})\delta_k]PI_{kt-1}$$

where r_{jt} is the nominal rate of return in sector j, and $1+\pi_{kt} = PI_{kt} / PI_{kt-1}$ is the rate of asset inflation.

The total value of capital services is given by the capital row of the Use matrix, as expressed in eq. (24) above. The values for 2000 are given in Table 1 in the column marked "Capital Input". The rate of return is calculated such that the sum of the services over all asset types is equal to this value for each industry:

(32) $$P_{Kjt}K_{jt} = \sum_k P_{Kkjt}K_{kjt} = \sum_k P_{Kkjt}S_{kjt-1}$$

With this we can now give the expression for the quantity of capital services in eqs. (2) and (3) as the aggregate of all assets :

(33) $$d\ln K_{jt} = \sum_k \overline{v}^K_{kjt} d\ln K_{kjt} = \sum_k \overline{v}^K_{kjt} d\ln S_{kjt-1} ,$$

$$v^K_{kjt} = \frac{P_{Kkjt}K_{kjt}}{\sum_a P_{Kajt}K_{ajt}}$$

That is, the weight for each asset type is the rental cost which depends on the common rate of return and an asset specific rate of depreciation. This makes our capital input index different from those that use a simple linear sum of asset types.

Due to the lack of data on land valuation and rents, we make no distinction about the types of land, and make a simple estimate for the rental value in the Agriculture sector. We ignore land for the other industries which means that we might be overestimating the return to capital in the mining and real estate sectors. For the same reason the return to aggregate capital may be overestimated.

(c) Labor input.

The methodology to construct labor input indices by industry is similar to that used in Jorgenson, Ho and Stiroh (2005, Chapter 6). The details are given in Yue et. al. (2005) and Ren and Sun (2005), here we summarize the implementation procedures. Our approach recognizes that a simple sum of workers is not a good measure of effective labor input since there is great heterogeneity in the work force. The marginal product of different types of workers is very different as reflected by their wages.

We express labor input for each industry as a Divisia aggregate over workers distinguished by sex, age and educational attainment using wages as weights, just as capital input is an aggregate over various asset types. The categories are:

Sex	1. Male 2. Female
Educational Attainment	1. College 2. High School 3. Junior High School 4. Elementary School 5. No schooling
Age	1. 16-34 2. 35-54 3. 55+

There are a total of 2x5x3=30 groups for the 720 million workers. The annual hours worked by all the workers in group *l* in industry *j* is denoted by H_{ljt}.

We assume that the effective labor services for each category of labor is proportional to the hours worked:

(34) $L_{ljt} = q_l^L H_{ljt}$, l=1,2,...70

The proportionality constant is represented by q to denote "quality", this is assumed to be constant over time. The hours worked is the product of the number of workers, the average hours per week (h_{lj}), and the average weeks per year (w_{lj}):

(35) $H_{ljt} = N_{ljt} h_{ljt} w_{ljt}$

The growth of effective labor input in industry j is a weighted average of the growth rates of all the categories:

(36) $d \ln L_{jt} = \sum_l \bar{v}_{ljt}^L d \ln L_{ljt} = \sum_l \bar{v}_{ljt}^L d \ln H_{ljt}$,

where the weights are the value shares (denoting hourly compensation by P_{Llj}):

$$v_{ljt}^L = \frac{P_{Lljt} L_{ljt}}{\sum_{a=1}^{70} P_{Lajt} L_{ajt}}$$

The second equality in (36) is given by (34).

The data of the number of workers by demographic groups for the benchmark years are based on the Population Censuses (1982, 1990, 2000), and the Sample Population Surveys (1987, 1995). The number of workers in other years is estimated from the Labor Force of Society series prior to 1990, and since 1990, from the annual Population Change Surveys. There is no good data on work hours, we use the hours data in the 1995 Sample Population Survey, and incorporate the changes in institutional arrangements for working time over the period 1982-2000. The number of workers for each industry in 2000 is given in the last column of Table 1.

The relative costs of the different types of workers are estimated using the Chinese Household Income Survey (CHIP) for the years 1987, 1995 and 2000, conducted by the Chinese Academy of Social Sciences in collaboration with other institutes. The wage rates from the survey are scaled such that the sum over all categories of workers is equal to the total value of labor compensation in *j* as given in the Input-Output table. Recall how eq. (26) expresses the total output of industry j as the sum of capital, labor and intermediate input values. That is:

(37) $$P_{Ljt} L_{jt} = \sum_{l} P_{Lljt} L_{ljt}$$

We interpolate the wage rates in between the three income survey years and scale them according to eq. (37) in the same way. The value of industry labor is given in Table 1, in the column marked "Labor input".

The price of total labor in industry j is this nominal value divided by the quantity index given in (36):

(38) $$P_{Ljt} = \frac{\sum_{l} P_{Lljt} L_{ljt}}{L_{jt}}$$

This labor input index, L_{jt}, is the one that enters into eqs. (3) and (4) for the productivity calculation.

V. Chinese Industry Productivity Performance

We begin by describing the snapshot view for year 2000 given in Table 1. We divide the economy into three industries: primary, secondary and tertiary industries. The total value added produced in the secondary industry is about equal to the sum of the primary and tertiary industries. The largest sector by value added or gross output of the secondary industry is construction, followed by electrical machinery, food products, chemicals, primary metal and non-electrical machinery. The smallest sector by gross output is gas utilities. The sectors with the largest stock of reproducible capital in the secondary group are electric utilities, oil and gas extraction and chemicals, while the sectors with the highest employment are construction and electrical machinery. The primary and tertiary industries use much more labor input than the secondary industry. The sum of capital and labor value-added is GDP, which was 9116 bil. *yuan* in 2000.

Place table 1 here.

Table 2 gives the growth rates of output and all factor inputs, first averaged over the whole period 1982-2000, and then averaged over 1994-2000. Output growth (first column) has been rapid in all sectors of the economy, in particular the secondary industry which averaged 11.4% per year. The rapid growth decelerated in 1994-2000 for the secondary and tertiary industries but accelerated for primary industry. For the whole period 1982-2000, the most rapid growth are in Electrical machinery (23%), paper and allied products (19%) and lumber & wood (16%). Other industries with double-digit growth rates are furniture and fixtures, apparel, transportation equipment, and instruments.

Place table 2 here.

The growth of sectoral capital and labor input are reported in the next two columns of Table 2. Recall that our factor inputs are aggregate indices of the components, as given in eqs. (33) and (36). The growth rates for capital are mostly less than 10% for the whole period 1982-2000, much lower than the growth rate of gross output. But for some sectors such as construction, lumber and wood, electric utilities, paper and allied products, and transportation equipment, capital input increased very rapidly during 1994-2000. This is part of the well known boom in construction, electric utilities and motor vehicles in this period.

The change in labor input is as expected, with a larger growth in labor intensive manufacturing, such as apparel, lumber and wood, leather, lumber and wood, as well as the energy sectors – electric utilities and gas utilities. For the sub-period 1994-2000, labor input fell for the mining sectors and seven manufacturing sectors including machinery and textile mills. This may due to the weak performance or restructuring of the SOEs resulting in worker layoffs. However, in the same period for these sectors, capital input growth is quite rapid. The growth rate of capital input even exceeds the growth rate of gross output for some sectors such as oil and gas extraction, construction, lumber and wood and apparel. This may be an indication of over-investment in these sectors.

The third and fourth columns show the growth rates of energy and material inputs. We can see that for most of the sectors, there is substantial energy conservation, while the growth rate of material input is similar to the growth rate of gross output.

We now turn to changes in total factor productivity as defined in eqn. (3). The TFP results, averaged over 1982-2000 and four sub-periods, are reported in Table 3. We can see that TFP growth is quite varied – many energy industries (utilities and petroleum refining) show negative TFP growth rates while electrical machinery, paper & allied products and machinery see very high rates exceeding 4% per year. Sectors with TFP growth exceeding 3% annually for the whole period include furniture and fixtures, transportation equipment, and instruments.

The puzzling phenomenon of negative TFP growth is a much discussed issue with commentators trying to identify the main sources of mismeasurement. We cannot address these issues in detail here, but note the following. The capital stock that has been growing so rapidly in these sectors may not have been fully utilized. Also, as in other countries, environmental regulation for the energy industries means that more inputs are used to make the production process cleaner but that is not counted in the measures of output. For example, an electric plant with desulfurization equipment has a bigger capital input but generates less net electricity. Finally, our assumption of the same depreciation rate in 1982 as in 2000 may be very poor given the rapid change in the quality of investment goods.

Place table 3 here.

Apparel is a major export sector in the post-reform China, and it has moderate TFP growth for the whole period 1982-2000, however, for the late 90s TFP growth was actually negative (-2.1%). Other sectors that have negative TFP growth during 1994-2000 include oil & gas mining, construction, food and electric utilities. On the other hand some sectors had very high TFP growth during the most recent sub-period – Primary Industry (5.0%), primary metals (6.5%), petroleum and coal products (5.4%), electrical machinery (4.0%), and stone, clay & glass (3.7%). The tertiary industry had a continuous deceleration of TFP growth, from 4.5% during 1982-84, to 1.2% during 84-88 and to -3.5% for 94-2000. It should be noted that Jorgenson, Ho and Stiroh (2005) also finds negative TFP growth in many U.S. service sectors.

Overall, comparing the different sub-periods, we find that productivity growth is very high for many sectors in the 1982-1988 period, with a slow down in 1988-1994, and really poor performance during 1994-2000 outside of agriculture. This deceleration does not augur well for the future if sustained.

We should note some caveats here. The gross output of a sector at the 2-digit level includes a large intra-sector transaction, which some analysts exclude from both input and output accounts. Excluding it gives a somewhat different picture of productivity growth.

Secondly, we find that the Oil & gas mining, electric utilities sector and other energy sectors had a large negative estimated TFP growth. As we noted, we do not have estimates of land input for the mining sectors and this may well play a role in producing such an implausible estimate. Another point to note is the large effect of the economic reforms during this period on prices of this sector. Before these sectors were deregulated, their input prices were highly subsidized, that is, they were buying at lower prices than other sectors. However, we assumed that all purchasers pay the same price for a given commodity. After deregulation, the input prices for these sectors converged to the average price and thus we may have overestimated the growth rate of intermediate inputs. Deregulation also raises the output price of these energy sectors, to the extent that these were not correctly captured in the price indices the growth rate of the gross output is also underestimated. All these give a downward bias to TFP growth.

VI. Aggregate Productivity Change and Decomposition of GDP Growth

We now describe the results of applying our three aggregation methods. First we report the contribution of each industry to value-added growth and to TFP growth using Domar weights as given in eqs. (21) and (23). Table 4 gives the results for the whole sample period 1982-2000 and Table 5 for 1994-2000. The column "V-A weight" gives the value added share $\overline{w}_j$, "V-A growth" gives the growth rate, $\Delta \ln V_j$, and "contribution to agg VA" gives the product $\overline{w}_j \cdot \Delta \ln V_j$, all averaged over the sample period. In the last four columns for TFP growth, we report the Domar-weight ($D_j = \overline{w}_j / \overline{v}_{V,j}$) which is roughly gross output of *j* divided by GDP, the growth rate of TFP ($d \ln A_{jt}$), the Domar-weighted contributions ($\sum_j \bar{w}_j / \bar{v}_{V,j} d \ln A_{jt}$), and finally, the share contribution to aggregate TFP growth. The last column sums to 100%.

Place table 4 and table 5 here.

For the whole period 1982-2000 the weighted sum of industry TFP growth (the first term on the right side of eq. 23) is 2.7% per year. Of this 2.7%, agriculture with its large share of GDP is the biggest contributor with 0.91 percentage points. This is followed by sectors that are small, but with rapid TFP growth – electrical machinery with 0.51 points, and non-electronic machinery with 0.43 points. The dampers are those with negative TFP growth – services (Tertiary Industry) with -0.31 points, and oil and gas extraction with -0.30 points. For the 1994-2000 subperiod not shown in these tables, the Domar-weighted sum of industry TFP is only 0.83%. For the 1994-2000 period in table 4, the weighted TFP growth contribution of primary industry (agriculture) rose to 1.59 percentage points, followed by primary metals with 0.84, electrical machinery with 0.60, and stone, clay and glass with 0.45. For this most recent subperiod, the biggest dampers are still the tertiary industry, electric utilities, construction, and food products.

The production possibility frontier defines GDP as an index over industry value added (eq. 18). Table 6 gives the growth rate in the aggregate output for the various sub-periods in the first line. The next two lines give the growth rate of aggregate capital and labor input. Over the entire sample period aggregate value added grew at 8.91% per year with the fastest growth in the first sub-period and the slowest during 1988-94.

Place table 6 here.

The last three lines of Table 6 give the contributions to this aggregate output growth (eq. 20). Of the 8.9% growth, capital contributed 4.6 percentage points, labor 1.8

and TFP 2.5. Compared to the post-War U.S. this is a large TFP growth, but like the U.S. the biggest sources is capital input growth. There is a great deal of variation among the various sub-periods, aggregate TFP during the agricultural reforms of 1982-1984 was the fastest at 9.1%, while it was -0.3% during 1994-2000. TFP growth was about 3% during 1984-94. Labor input contribution was roughly stable at about 2 percentage points in all sub-periods, but capital contribution was small in the first sub-period. Except for 1982-84, in the other periods, capital input was the largest source of aggregate growth.

The aggregate production function approach defines GDP as the simple sum of industry value added (eq. 11), and this is not exactly equal to the official real GDP. Recall that this imposes the assumption of identical value added price for all sectors. The first 3 lines in Table 7 give the growth rate of output using the 3 methods. For the entire sample 1982-2000, the aggregate PPF method estimates aggregate value added growth at 8.91% per year, whereas the aggregate production function method give 8.29%, the -0.62 percentage points difference being attributed to the reallocation of value added.

Place table 7 here.

The difference of growth rates between these two methods is quite volatile over the various sub-periods. For the first three sub-periods, the PPF gives a higher growth rate, whereas for 1994-2000 the aggregate production function method is faster (8.74% vs. 7.96%). The comparisons for the U.S. given in Jorgenson, Ho and Stiroh (2005, Table 8.4) also show a similar volatility.

The bottom half of Table 7 compares the PPF to the direct aggregation across industries using the TFP decomposition eq. (23). This links aggregate TFP growth to the Domar weighted sum of industry TFP growth and the reallocation of capital and labor.

For the whole period 1982-2000, of the 2.51% aggregate TFP growth, 2.7% is due to the industry TFP growth, -0.17% to reallocation of capital input, and -0.02% to reallocation of labor. That is, the individual sectors of the economy performed well, but the sectors that expanded relatively more included the poor performers. The movement of labor contributed little to the reallocation effects; most of the negative contribution is due to the reallocation of capital. The reallocation of capital has a positive effect for most of the 80s, but negative after 1988.

When we divide the whole economy into primary, secondary and tertiary industries, we find that the main source of the Domar-weighted TFP growth is from the secondary industry, of the 2.70% during 1982-2000, secondary industry contributed 2.1 percentage points, while primary industry contributed 0.9 points and tertiary -0.3 points. Over the various sub-periods, the Domar-weighted sum was decelerating, from 7.5% during 1982-84, to 2.9% during 1988-94, and to 0.8% during 1994-2000. As we noted earlier, this sum is dominated by the secondary and tertiary industries, both of which showed this rapid deceleration. TFP of the tertiary industry grew at a rapid 2.0% during 1982-1984, but slowed to a 0.6% rate during 1984-88, to 0.1% during 1988-1994, and even registered a negative -2.1% for 1994-2000. The primary industry was different with a steady TFP growth except for 1984-88.

VII. Conclusion

We have laid out a methodology to account for Chinese economic growth, both at the sectoral level and at the aggregate level. We implemented this to estimate the productivity performance for China during the post-reform period using a time-series of input-output tables that is part of a consistent set of National Accounts, and detailed labor data from the micro-level surveys.

Aggregate TFP growth for the post-reform period 1982-2000 is estimated at 2.5%, which is in between the low estimates of 1.1 – 1.4% from Woo (1998) and Young (2003), and the high estimates of 4-5% of Hu and Khan(1997). This is similar to the estimates in Ren and Sun (2005), and Wang and Yao (2001). By dividing the whole period into four sub-periods we find a very high TFP growth of 9.1% during 1982-1984, a high growth during 1984-1988 and 1988-1994, but a negative TFP growth for 1994-2000, which suggest a declining trend of future TFP growth. Thus our study support the results in Woo (1998), Young (2003), and Ren and Sun (2005), but different from Chow and Li (2002), Borensztein and Ostry (1996), Fan, Zhang and Robinson (1999), and Hu and Khan (1997).

Unlike these previous studies, we also decomposed the aggregate TFP growth into contributions from sectoral TFP, reallocation of value added, as well as reallocation of capital and labor inputs. Our results suggest that the main contribution comes from the Domar-weighted sectoral TFP, while the reallocation of labor is negligible. The efficiency improvement due to the reallocation of capital is positive in the 80s, but negative in the 90s. GDP growth was driven by technical progress and efficiency improvements in the 1982-1994 sub-period, in other periods it is mainly driven by the accumulation of capital. Aggregate TFP was moderate and even negative for some years during the late 1990s.

Looking at industry TFP contribution to aggregate TFP growth, we find that the Tertiary industry contributed about 20-30% in the 1980s, a fairly small share in early 1990s and was negative in the late 1990s.

As the other studies of productivity has noted, the quality of data leaves much to be desired. We believe that our data set is an improvement over those used in previous studies, however, we still need to consider the poor data in some sectors, in particular the service sectors. Nevertheless, our results at this stage are suggestive. The agriculture sector showed good productivity gains, as did many manufacturing sectors. However, many other manufacturing industries showed negative productivity growth. Deregulation of prices in the energy-intensive sectors and other government regulated sectors, may have biased the TFP growth estimates downwards.

REFERENCES

Borensztein, Eduardo and Jonathan Ostry, “Accounting for China’s growth performance,” *American Economic Review*, Vol. 86, 224-228, 1996.

Chow, Gregory, *China’s Economic Transformation*, Blackwell Publishing, 2002.

Chow, Gregory, “Capital Formation and Economic Growth in China,” Quarterly Journal of Economics, Vol. CVIII, No. 3, 809-842, August 1993.

Chow, Gregory and Kui-Wai Li, “China’s economic growth: 1952-2010,” *Economic Development and Cultural Change*, Vol. 51, 247-256, 2002.

Fan, Shanggen, Xiaobao Zhang, and Sherman Robinson, “Past and future sources of growth for China”, EPTD discussion paper No. 53, International Food Policy Research Institute. Washington, D.C., 1999.

Gu, Wulong and Mun Ho, “A Comparison of Productivity Growth in Canada and the U.S.”, American Economic Review, May 2000.

Groves, Theodore, Yongmiao Hong, John McMillan and Barry Naughton, “Autonomy and Incentives in Chinese State Enterprises,” *Quarterly Journal of Economics*, Vol. 109, No.1 February, p 185-209, 1994.

Ho, Mun and Dale Jorgenson, “The Quality of the U.S. Work Force, 1948-95,” mimeo, Harvard University, 1999.

Hu, Zuliu and Mohsin Khan, “Why is China growing so fast?” IMF Staff Papers (44), 103-131, 1997.

Jefferson, Gary, Thomas Rawski and Yuxin Zheng, “Chinese Industrial Productivity: Trends, Measurement Issues, and Recent Developments,” *Journal of Comparative Economics*, Vol. 23, 146-180, 1996.

Jefferson, Gary, Thomas Rawski, Li Wang and Yuxin Zheng, "Ownership, Productivity Change and Financial Performance in Chinese Industry," *Journal of Comparative Economics*, Vol. 28, No. 4, 786-813, 2000.

Jorgenson, Dale, Masahiro Kuroda and Kazuyuki Motohashi (2007) *Productivity in Asia: Economic Growth and Competitiveness*, Edward Elgar.

Jorgenson, Dale, Frank Gollop and Barbara Fraumeni, *Productivity and U.S. Economic Growth*, Harvard University Press, Cambridge, MA, 1987.

Jorgenson, Dale, Mun Ho and Kevin Stiroh, *Information Technology and the American Growth Resurgence*, Cambridge, MA: MIT Press, 2005.

Jorgenson, Dale and Kevin Stiroh, "U.S. Economic Growth at the Industry Level," American Economic Review, May 2000.

Lin, Yifu, Fang Cai, and Zhou Li, The Chinese Miracle: Development Strategy and Economic Reform, Shanghai People Publishing House, Shanghai, 2002.

Maddison, Angus and Harry Wu, "China's Economic Performance: How Fast has GDP Grown; How Big is it Compared with the USA," Working paper, 2006.

OECD, "National Accounts for China: Sources and Methods," OECD Centre for Cooperation with Non-Members, 2000.

Perkins, Dweight and Thomas Rawski, "Forecasting China's Economic Growth to 2025," in Loren Brandt and Thomas G. Rawski (eds), China's Great Economic Transformation, Cambridride University Press, forthcoming in 2008.

Rawski, Thomas, "China by the Numbers: How Reform Affected Chinese Economic Statistics," mimeo, University of Pittsburgh, 2000.

Ren, Ruoen, "China's Economic Performance in an International Perspective," OECD Development Centre Studies, 1997.

Ren, Ruoen, "China's Economic Performance in International Perspective," Manuscript. Paris: OECD Development Centre, October 1995.

Ren, Ruoen and Lin Lin Sun, "Total Factor Productivity Growth in China Industries: 1981-2000," presented at the 5th International Input-Output Conference Beijing, China, June 27-July 1, 2005

State Statistical Bureau, (Zhongguo Tongji Nianjian) *China Statistical Yearbook*, China Statistical Publishing House, Beijing, 1981-2002.

State Statistical Bureau, *Input-Output Table of China 1992*, China Statistical Publishing House, Beijing, 1996.

State Statistical Bureau, "China Statistical Yearbook on Investment in Fixed Assets (1950-1995)," China Statistics Press, Beijing, 1997.

State Statistical Bureau, *The Gross Domestic Product of China, 1952-1995*, Finance and Economic Press, Dongbei University, 1998.

Wang, Yan and Yudong Yao, "Sources of China's Economic Growth, 1952-99: Incorporating Human Capital Accumulation," World Bank working paper, 2001.

Woo, Wing Thye, "Chinese Economic Growth: Sources and Prospects," in M. Fouquin and F. Lemoine (eds.) *The Chinese Economy*, Economica, London, 1998.

Woo, Wing Thye, Wen Hai, Yibiao Jin and Gang Fan, "How Successful Has Chinese Enterprise Reforms Been? Pitfalls in Opposite Biases and Focus," *Journal of Comparative Economics*, June 1994.

Xu, Xianchun. Liping Liu, Shuchang Qi, Lihua Dong, Haiyan Wang, Tonglu Zhao, Xiangqian Ma, Xiaoqin Li, and Ruoen Ren, "A Study on an Internationally Comparable Time Series of China's Use Tables: 1981-2000," presented at the 15th International Input-Output Conference Beijing, China, June 27-July 1, 2005

Young, Alwyn, "Gold into Base Metals: Productivity Growth in the People's Republic of China during the Reform Period," *Journal of Political Economy*, Vol. 111, 1221-1261, 2003.

Yue, Ximing, Yukun Lin, Ruoen Ren, "Labor Input in China: 1982-2000," prepared for the International Comparison of the Productivity among Pan-Pacific Countries (Asian Countries) – ICPA Project No. 3, 2005.

Table 1. Characteristics of the Chinese Economy of Year 2000

Sector	Output bil. Yuan	Capital Input bil. Yuan	Labor input bil. Yuan	Energy input bil. Yuan	Material input bil.Yuan	Capital Stock bil. Yuan	Employ-ment million
I. Primary Industry	**2492**	**544**	**969**	**62**	**917**	**7338**	**464**
II. Secondary Industry	**18131**	**2496**	**2168**	**1825**	**11642**	**7137**	**121**
Coal mining	253	36	61	31	126	446	4.1
Metal & nonm. mining	336	61	64	37	174	163	2.9
Oil and gas extraction	578	272	69	146	92	923	0.5
Construction	2202	146	466	168	1422	264	19.3
Food products	1613	295	137	29	1152	309	8.5
Textile mill products	1045	127	96	19	803	155	8.7
Apparel	448	50	61	5	331	12	8.1
Lumber and wood	101	13	11	5	72	32	2.5
Furniture and fixtures	179	20	22	4	133	6	2.6
Paper and allied	306	32	43	20	212	75	1.9
Printing, publishing	92	13	11	2	66	31	1.5
Chemicals	1557	212	130	203	1012	802	5.6
Petroleum, coal prod	818	112	39	488	178	206	0.6
Leather	239	25	31	2	181	14	3.2
Stone, clay, glass	1000	130	124	131	614	199	7.3
Primary metal	1277	139	132	179	828	691	3.1
Fabricated metal	536	61	60	30	384	38	4.8
Machinery, non-elect	1055	137	133	45	740	278	7.7
Electrical machinery	2037	208	213	32	1583	181	7.8
Motor vehicles	453	61	42	14	336	107	2.2
Transportation equip	268	24	27	6	211	145	3.3
Instruments	107	13	15	2	77	27	1.1
Rubber and plastics	565	65	49	20	431	43	3.4
Misc. manufacturing	421	59	56	14	293	160	5.8
Electric utilities	607	178	69	176	184	1761	4.2
Gas utilities	37	6	5	17	9	69	0.3
III. Tertiary Industry	**6153**	**1385**	**1555**	**331**	**2883**	**9585**	**136**
Total	***26776***	***4424***	***4692***	***2219***	***15442***	***24061***	***721***

Table 2. Sectoral output and inputs (growth rates % per annum)

Sector	Output 82-00	Output 94-00	Capital input 82-00	Capital input 94-00	Labor input 82-00	Labor input 94-00	Energy input 82-00	Energy input 94-00	Material input 82-00	Material input 94-00
I. Primary Industry	**6.9**	**8.9**	**3.0**	**5.9**	**2.2**	**0.8**	**6.3**	**11.5**	**7.9**	**5.4**
II. Secondary Industry	**11.4**	**10.2**	**6.7**	**9.2**	**3.3**	**2.6**	**9.7**	**12.0**	**13.3**	**11.5**
Coal mining	7.2	6.7	5.7	6.9	0.5	-4.6	5.1	3.2	11.2	9.0
Metal & nonm. mining	10.3	8.3	7.4	5.0	0.2	-3.5	9.4	5.2	13.8	7.4
Oil and gas extraction	1.4	6.2	11.6	9.7	3.2	-0.8	10.6	18.5	11.7	13.3
Construction	9.2	9.1	8.8	15.7	4.5	8.9	11.8	29.0	10.8	11.8
Food products	9.8	7.1	8.5	7.8	4.3	3.4	11.5	6.7	10.3	10.1
Textile mill products	8.9	6.7	3.7	0.3	2.5	-4.0	7.7	3.0	8.6	6.5
Apparel	14.6	4.6	1.6	10.2	6.4	10.4	17.5	12.6	15.3	5.6
Lumber and wood	15.9	10.2	6.6	18.3	7.5	11.3	8.4	1.2	17.1	8.7
Furniture and fixtures	15.7	10.7	0.5	6.3	3.1	7.2	9.9	7.8	17.0	9.7
Paper and allied	18.9	11.4	6.7	13.0	2.7	-0.3	15.7	8.7	18.7	12.8
Printing, publishing	12.9	4.2	6.3	6.8	4.1	0.4	10.3	12.4	13.2	4.6
Chemicals	12.3	10.3	8.1	12.1	2.6	-1.9	6.9	9.0	13.6	12.5
Petroleum, coal prod	6.6	16.1	9.6	8.3	3.6	0.5	3.9	8.7	15.4	17.9
Leather	15.5	5.8	1.3	-3.1	7.5	13.9	14.6	8.0	16.5	7.0
Stone, clay, glass	14.2	9.8	8.7	6.4	0.9	-1.1	9.8	4.3	17.3	8.0
Primary metal	10.8	15.7	6.4	8.3	2.7	-1.6	5.9	9.6	11.8	10.9
Fabricated metal	12.9	8.8	2.2	5.0	1.9	4.0	10.1	10.0	13.5	8.9
Machinery, non-elect	13.3	9.7	0.4	2.5	0.4	-4.8	8.5	8.5	13.8	10.5
Electrical machinery	23.0	24.2	9.3	11.3	5.4	6.3	14.3	15.8	21.2	23.7
Motor vehicles	13.6	9.6	6.9	11.6	4.4	5.3	10.1	14.1	13.0	9.5
Transportation equip	14.4	9.9	5.0	13.2	4.8	3.5	4.1	6.6	14.4	12.3
Instruments	14.1	16.0	1.4	2.4	-0.9	-2.8	8.9	14.1	15.7	17.2
Rubber and plastics	10.9	9.8	-2.0	6.6	4.2	3.2	10.7	13.3	12.4	11.9
Misc. manufacturing	10.3	8.9	8.7	13.1	2.0	8.8	12.2	14.9	11.4	8.8
Electric utilities	9.4	9.3	11.2	17.9	7.3	9.8	8.4	11.4	17.7	15.6
Gas utilities	12.7	10.1	16.7	11.0	12.7	13.9	13.8	13.1	18.8	10.0
III. Tertiary Industry	**10.5**	**7.2**	**13.9**	**15.3**	**6.8**	**8.6**	**5.5**	**8.9**	**12.0**	**9.9**

Table 3. Sectoral total factor productivity growth (% per annum)

	Total Factor Productivity				
Sector	**82-00**	**82-84**	**84-88**	**88-94**	**94-00**
I. Primary Industry	**2.6**	**4.1**	**-1.4**	**2.2**	**5.0**
II. Secondary Industry	**1.4**	**3.0**	**2.1**	**1.3**	**0.7**
Coal mining	0.8	4.9	1.8	-3.1	2.6
Metal & nonm. mining	1.2	-1.9	0.8	-0.2	3.7
Oil and gas extraction	-10.0	-7.6	-18.1	-10.7	-4.6
Construction	-0.2	0.2	2.8	0.5	-3.2
Food products	0.2	0.8	0.8	1.9	-2.0
Textile mill products	1.6	0.9	4.0	-0.4	2.3
Apparel	2.7	5.6	6.4	3.9	-2.1
Lumber and wood	2.4	-2.7	4.2	5.0	0.1
Furniture and fixtures	3.4	1.3	3.3	5.8	1.9
Paper and allied	4.8	9.5	10.3	3.7	0.8
Printing, publishing	2.4	5.1	5.1	2.3	-0.2
Chemicals	1.6	4.7	2.2	2.2	-0.5
Petroleum, coal prod	-1.5	4.9	-15.7	-1.1	5.4
Leather	2.2	8.2	4.5	1.9	-0.9
Stone, clay, glass	2.2	1.3	2.7	0.8	3.7
Primary metal	1.6	3.2	-1.6	-1.8	6.5
Fabricated metal	2.9	4.4	4.1	3.5	0.9
Machinery, non-elect	4.1	9.1	6.9	2.3	2.5
Electrical machinery	5.6	6.4	8.6	4.9	4.0
Motor vehicles	2.9	10.0	5.4	1.8	0.0
Transportation equip	3.1	9.6	5.4	3.9	-1.3
Instruments	3.9	4.1	3.9	3.8	3.8
Rubber and plastics	2.4	8.1	3.4	2.8	-0.5
Misc. manufacturing	0.6	0.8	2.4	0.7	-0.7
Electric utilities	-2.0	2.0	0.0	-1.4	-5.1
Gas utilities	-2.7	-1.0	-5.2	-2.5	-1.8
III. Tertiary Industry	**-0.6**	**4.5**	**1.2**	**0.1**	**-3.5**

Table 4. Domar-weight decomposition of productivity growth (1982-2000)

Sector	V-A Weight	V-A Growth	Contri- bution to agg. V-A	Domar weight	TFP growth	Wighted TFP growth	Share of agg. TFP growth
	Value-Added			**Total Factor Productivity**			
I. Primary Industry	**0.240**	**0.065**	**0.015**	**0.363**	**2.564**	**0.909**	**0.337**
II. Secondary Industry	**0.467**	**0.100**	**0.047**	**1.547**	**1.360**	**2.103**	**0.779**
Coal mining	0.014	0.036	0.001	0.030	0.765	0.022	0.008
Metal & nonm. mining	0.014	0.078	0.001	0.032	1.149	0.049	0.018
Oil and gas extraction	0.019	-0.051	-0.001	0.030	-9.948	-0.301	-0.111
Construction	0.058	0.051	0.003	0.206	-0.245	-0.060	-0.022
Food products	0.045	0.085	0.004	0.162	0.217	0.017	0.006
Textile mill products	0.033	0.096	0.003	0.131	1.620	0.194	0.072
Apparel	0.010	0.131	0.001	0.038	2.658	0.075	0.028
Lumber and wood	0.002	0.153	0.000	0.008	2.349	0.020	0.007
Furniture and fixtures	0.004	0.138	0.001	0.013	3.430	0.047	0.017
Paper and allied	0.006	0.204	0.001	0.023	4.837	0.074	0.027
Printing, publishing	0.003	0.126	0.000	0.011	2.399	0.021	0.008
Chemicals	0.037	0.117	0.004	0.124	1.593	0.180	0.067
Petroleum, coal prod	0.013	0.100	0.001	0.042	-1.489	0.013	0.005
Leather	0.005	0.124	0.000	0.019	2.216	0.020	0.008
Stone, clay, glass	0.030	0.124	0.004	0.090	2.234	0.222	0.082
Primary metal	0.032	0.117	0.004	0.116	1.567	0.222	0.082
Fabricated metal	0.014	0.123	0.002	0.050	2.881	0.137	0.051
Machinery, non-elect	0.036	0.125	0.004	0.113	4.143	0.428	0.158
Electrical machinery	0.027	0.280	0.008	0.106	5.584	0.514	0.191
Motor vehicles	0.012	0.147	0.002	0.041	2.901	0.109	0.040
Transportation equip	0.006	0.141	0.001	0.022	3.140	0.055	0.020
Instruments	0.003	0.117	0.000	0.008	3.857	0.031	0.011
Rubber and plastics	0.013	0.076	0.001	0.049	2.422	0.106	0.039
Misc. manufacturing	0.012	0.077	0.001	0.042	0.609	0.020	0.008
Electric utilities	0.020	0.056	0.001	0.042	-1.960	-0.106	-0.039
Gas utilities	0.001	0.071	0.000	0.002	-2.718	-0.006	-0.002
III. Tertiary Industry	**0.294**	**0.093**	**0.027**	**0.555**	**-0.565**	**-0.313**	**-0.116**
Aggregated weighted TFP growth	**1.000**		**0.089**			**2.70**	**1.000**

Note: The "weighted TFP growth" is the first term on the right of eq. (18), $D_{jt} d \ln A_{jt}$, where the weights are gross output divided by GDP.

Table 5. Domar-weight decomposition of productivity growth (1994-2000)

Sector	V-A Weight	V-A Growth	Contri-bution to agg. V-A	Domar weight	TFP growth	Wighted TFP growth	Share of agg. TFP growth
	Value-Added			**Total Factor Productivity**			
I. Primary Industry	**0.194**	**0.109**	**0.021**	**0.315**	**5.036**	**1.586**	**1.904**
II. Secondary Industry	**0.506**	**0.090**	**0.045**	**1.816**	**0.735**	**1.334**	**1.602**
Coal mining	0.013	0.057	0.001	0.031	2.589	0.077	0.093
Metal & nonm. mining	0.015	0.104	0.002	0.038	3.725	0.140	0.168
Oil and gas extraction	0.022	0.001	0.000	0.036	-4.603	-0.204	-0.245
Construction	0.068	0.001	0.000	0.233	-3.158	-0.733	-0.879
Food products	0.050	-0.010	0.000	0.183	-2.016	-0.367	-0.441
Textile mill products	0.028	0.075	0.002	0.114	2.311	0.264	0.317
Apparel	0.014	0.028	0.000	0.052	-2.111	-0.107	-0.129
Lumber and wood	0.003	0.154	0.001	0.011	0.135	0.004	0.004
Furniture and fixtures	0.005	0.135	0.001	0.019	1.906	0.036	0.043
Paper and allied	0.009	0.088	0.001	0.032	0.842	0.024	0.029
Printing, publishing	0.004	0.024	0.000	0.012	-0.210	0.000	0.000
Chemicals	0.038	0.055	0.002	0.147	-0.459	-0.029	-0.035
Petroleum, coal prod	0.012	0.330	0.004	0.052	5.422	0.347	0.417
Leather	0.008	0.024	0.000	0.029	-0.929	-0.028	-0.033
Stone, clay, glass	0.034	0.152	0.006	0.117	3.738	0.452	0.543
Primary metal	0.029	0.306	0.010	0.127	6.457	0.840	1.008
Fabricated metal	0.015	0.084	0.001	0.062	0.942	0.054	0.065
Machinery, non-elect	0.034	0.080	0.003	0.120	2.531	0.305	0.366
Electrical machinery	0.034	0.267	0.009	0.156	4.041	0.604	0.725
Motor vehicles	0.012	0.093	0.001	0.047	-0.033	0.002	0.002
Transportation equip	0.007	0.027	0.000	0.030	-1.311	-0.042	-0.050
Instruments	0.003	0.129	0.000	0.009	3.797	0.034	0.041
Rubber and plastics	0.013	0.030	0.000	0.057	-0.451	-0.025	-0.030
Misc. manufacturing	0.013	0.087	0.001	0.045	-0.689	-0.032	-0.038
Electric utilities	0.023	0.036	0.001	0.055	-5.136	-0.278	-0.333
Gas utilities	0.001	0.067	0.000	0.003	-1.844	-0.004	-0.005
III. Tertiary Industry	**0.300**	**0.043**	**0.013**	**0.601**	**-3.472**	**-2.087**	**-2.505**
Aggregated weighted TFP growth	**1.000**		**0.079**	**2.732**		**0.83**	**1.000**

Note: The "weighted TFP growth" is the first term on the right of eq. (18), $D_{jt} d \ln A_{jt}$, where the weights are gross output divided by GDP.

Table 6. Growth in Aggregate Value-added and its Sources; using production possibility frontier

	1982-2000	1982-1984	1984-1988	1988-1994	1994-2000
Value added (% p.a.)	8.91	12.50	10.2	7.81	7.96
Capital input (% p.a.)	8.75	3.11	8.84	6.73	12.58
Labor input (% p.a.)	3.89	3.73	4.66	3.41	3.91
Contribution to aggregate growth (eq. 20)					
Capital	4.57	1.72	4.83	3.58	6.33
Labor	1.83	1.66	2.11	1.59	1.94
Aggr. TFP	2.51	9.12	3.26	2.64	-0.31

Table 7. Aggregate Reallocation Effects (% per year)

	1982-2000	1982-1984	1984-1988	1988-1994	1994-2000
Agg. Production Possibility Frontier vs. Agg. Production Function					
Agg Prod. Func. Value added	8.29	11.12	7.73	7.28	8.74
Agg. PPF Value added	8.91	12.50	10.2	7.81	7.96
Reallocation of value added	-0.62	-1.38	-2.47	-0.53	0.78
Agg. Production Possibility Frontier vs. Direct Aggregation Across Industries					
Aggregate TFP	2.51	9.12	3.26	2.64	-0.31
Domar weighted productivity	2.70	7.48	2.78	2.92	0.83
--- Primary Industry	0.91	1.84	-0.55	0.89	1.59
--- Secondary Industry	2.10	3.67	2.71	1.94	1.33
--- Tertiary Industry	-0.31	1.96	0.62	0.08	-2.09
Reallocation of capital	-0.17	1.80	0.48	-0.28	-1.15
Reallocation of labor	-0.02	-0.15	0.00	0.00	0.00

Figure 1. Comparison of the GDP Growth during the Reform Period (1979-2000)