

# An Analysis on the Growth Attributes of Manufacturing Industries in China

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## Abstract

This paper examines the growth attributes of manufacturing industries in China for the sample period of 1999-2007. A revised Solow's growth decomposition method is used to consider four growth attributes of input growth, scale effect, technical progress, and technical efficiency change. For the aggregates of all industries, we found no technical efficiency change. The technical progress, input growth, and scale effect explain 45%, 38%, and 17% of output growth, respectively. When all manufacturing industries are disaggregated into four major groups and twenty-nine sub-manufacturing industries, we find that estimates exhibit increasing returns to scale and positive scale effect. When the manufacturing industries data are aggregated in different provinces and regions, we find that input growth is more significant in the Southern region than in other regions. Only the Southern region shows an increase in technical efficiency. Technical progress is more important in the Western and Northeastern regions than the other two regions.

## I Introduction

The base in the formation of the People's Republic of China prior to 1949 was the rural economy with peasants supporting the communist movement in the "long march". Industries were small scale and largely household oriented. After massive collectivization and the lean towards the Soviet Union in the 1950s, China inappropriately pursued heavy industries under the commune system. The industrial sector remained stagnant, if not deteriorated, in the Cultural Revolution of the 1960s and the subsequent rehabilitation of the 1970s. Change came in the pursuit of economic reform with a change of ideology under the late Deng Xiao-ping's motto that "it does not matter whether it is a black or white cat, so long as it catches mice". At the time of economic reform in 1978, China was faced with extreme economic imbalances (Perkins, 1988, 1994; Wu, 2005). For example, a severe industrial mismatch with excess supply in heavy industrial goods and excess demand in light manufacturing and consumer goods appeared. Due to massive poverty in the decades of the 1960s and 1970s, travelers from Hong Kong to Mainland China brought with them such basic necessities as clothing materials and cooking oil; however, these were replaced by such household electronic appliances as color televisions, air-conditions, refrigerators and washing machines in the 1980s.

Light manufacturing industries in China began to grow as a result of the open door policy in 1978. With the establishment of special economic zones (SEZs) that provided various investment advantages and low production cost along the coast of Southern China, foreign investments from Hong Kong and Taiwan provided the initial needed capital. It has been reported that 70% of utilized foreign investment in the Guangdong province in 2001 was originated from Hong Kong alone, though there could be other foreign and even Mainland investment that used Hong Kong as the transit base (Li, 2006, p. 370). Premier Zhao Ziyang called for industrial reform in the mid-1980s with the intention to restructure resources to light manufacturing in consumer products and the separation between party and managerial duties (Wu, 2005). However, it was not until the emergence of Premier Zhu Rongji in the early 1990s that the central authority in Beijing designated the development of Shanghai as an industrial powerhouse for high-technology industries. Subsequently, with the huge inflow of foreign direct investment, various provinces have provided investment advantages and expanded their industrial capacity that made China the "factory of the world" with growing export of manufacturing products since 2004.

After the large devaluation of the yuan in 1994, China's manufactured exports have expanded greatly. Between 1990 and 2007, for example, Chinese statistics show that the output of secondary industry as a percentage of GDP at current prices has increased from 41.3% to 48.6%. According to the National Bureau of Statistics of China, manufacturing is the largest sector occupying 48.3% of real GDP, followed by service sector with 40.2% and primary sector has fallen to 11.5% in 2006. Inflows of foreign direct investment to China since 1978 have largely concentrated in the manufacturing sector (Tuan and Ng, 2007; Ran *et al.*, 2007; Tuan *et al.*, 2009; Thompson, 2002).

Despite China's achievement of an average annual real economic growth of about 8% since economic reform in 1978, such growth issues as the rate of productivity growth and regional imbalances have been debated (Borenstein and Ostry, 1996; Young, 2000, 2003; Bosworth and Collins, 2008; Fleisher *et al.*, 2009; Liu and Li, 2006; Wan, 2004; Tong, 1999; Chang, 2002). The expansion of the manufacturing sector and the transformation from state-owned to non-state-owned enterprises is a key area in China's economic reform (Perkins, 1988). The 1997 state-owned enterprises reform has promoted the strategy of "grasping the large, releasing the small" (*juada fangxiao*) and increased the establishment of non-state owned enterprises (Wu, 2005). At the national level, Li (2009) has shown that state ownership is still the major form of ownership in China, but its percentage share has been caught up by other forms of non-state ownership.

The growth attributes of the secondary sector can provide insight and future direction in China's post-reform economy. The productivity and efficiency performance of industry has previously been conducted in individual industries in China, such as iron and steel, oil and aerospace, telecommunication and insurance (Jefferson, 1990; Movshuk, 2004; Ma *et al.*, 2002; Mu and Lee, 2005; Yao *et al.* 2007). In studying productivity changes in China's industries, the Malmquist index that decomposes productivity into efficiency and technological changes has been applied in Ma *et al.* (2002) and Movshuk (2004), while Sun *et al.* (1999) and Yao *et al.* (2007) agreed that stochastic frontier analysis and data envelopment analysis are the more effective approach to measure the technical efficiency of industry.

The reliability of Chinese data has been a concern. One China-watcher joked that Chinese data in general were inflated by 10% at each reporting level from individual units to provincial governments, from provincial governments to central authority, and from central authority to

actual release. A number of recent studies have debated on the problems of China's macroeconomic data (Young, 2000, 2003; Holz, 2004; Rawski and Xiao, 2001). In the case of industrial outputs, both Ren and Zheng (2006) and Szirmai *et al.* (2005) on the one hand, and Wu (2002) and Maddison and Wu (2008) on the other hand have used different benchmark years and industries to come up with their own set of industrial output data. Their studies summarized a number of problems in the reported industrial output data, including the change from the Marxian material product system to the system of national accounts of reporting, policy bias as officials distorted the statistics to achieve policy goals, rapid changing structure of Chinese industries and emergence of the service sector, and exchange rate distortion. Szirmai *et al.* (2005) has correctly pointed out that the construction of China's industrial data is needed more at the beginning stage of the reform era when data were missing. Maddison and Wu (2008) point to the short history in the development of Chinese industries, and echoed the argument in Chow and Li (2002) that discrete data problems will cancel out each other in a time series analysis.

This paper uses a more recent sample period (1999-2007) to study the growth factors in China's manufacturing industries. Data on 161 three-digit manufacturing industries in 31 provinces in China are collected. Our concern is the performance of manufacturing industries in China, which by now has passed through three decades of economic reform. In particular, this paper examines the core issues of advancement in industrial productivity, technological progress and efficiency in China's manufacturing sector. The stochastic frontier approach is used in the empirical analysis, because it drops Solow's (1975) assumption of constant return to scale and optimal production capacity, and instead assumes a non-constant return to scale and the possibility of deviations between actual and optimal output due to technical inefficiency. The growth in total factor productivity (TFP) is decomposed into three components of technical progress, technical efficiency change and scale effect (Aigner *et al.*, 1977; Kumbharkar and Lovell, 2000).

Section II shows the industrial data and the descriptive performance of industries in China. Section III discusses the methodology that decomposes total factor productivity into three separate attributes, while Section IV reports the empirical results at the aggregate and provincial levels, and the performance of different industries and provinces. The last section concludes the paper.

## II Industrial Data and Performance

The online data *Support System for China Statistics Application* from the All China Marketing Research (ACMR) in Beijing, China, provide a comprehensive industrial output and related information for a large number of four-digit manufacturing industries for the 31 provinces in China since 1999. The data for the 1999-2002 years show a total of 511 four-digit GB/T-94 coded manufacturing industries, but since 2003 the number has been reduced to 473 four-digit GB/T-2002 coded industries. The two sets of industry codes are compared, compiled and adjusted to eliminate classification and reporting inconsistencies. The standardized and adjusted four-digit manufacturing industries for the sample period of 1999-2007 are then aggregated into 161 three-digit and 29 two-digit industries, which are further grouped into four key industrial groups according to their digit category and level of technology, as shown in Table A1 in Appendix A. Both the Processing Industry and Light Manufacturing Industry are mainly labor-intensive industries. The Metal and Machinery Industry contains the traditional heavy industries, while the High-technology Industry relates closer to the technology-intensive industries. With a total of 161 industries in 31 provinces from 1999 to 2007, it gives about 29,812 data values after excluding missing observations. The number of observations for the four industrial groups in four regions is shown in Table A2 in Appendix A.

The 31 provinces and autonomous areas in China are geographically grouped into four regions. The Eastern region includes 11 provinces of Beijing, Tianjin, Hebei, Shanxi, Shanghai, Jiangsu, Zhejiang, Anhui, Shandong, Henan, and Hubei. The Southern region contains 8 provinces and autonomous areas of Fujian, Jiangxi, Hunan, Guangdong, Guangxi, Hainan, Chongqing, and Sichuan. The Western region consists of 9 inner provinces and autonomous areas of Inner Mongolia, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. The Northeastern region composes of the three provinces of Jilin, Heilongjiang and Liaoning.

The Eastern region includes several coastal provinces that lead to the high initial economic growth and export expansion after the open door policy. Since economic reform in 1978, the Southern region adjacent to Hong Kong and Taiwan has been the recipient of foreign direct investment that concentrated mainly in labor-intensive manufacturing. The Northeastern region adjacent to Japan and South Korea is the traditional heavy industry area, while the Western region is extremely remote and not easily accessible.

Table 1 summarizes the key data on the four groups of industries in four regions for the sample period. The total numbers of enterprises between 1999 and 2007 have doubled. The Metal and Machinery Industry, which is the traditional heavy industry, is the largest industrial sector in terms of industrial sales output value and the number of enterprises and employees. The Processing Industry that relies a lot on the agricultural sector is the second largest industry in terms of the number of enterprises and employees, indicating that the Processing Industry is the most labor-intensity industry. However, its industrial sales output value is the smallest among the four industrial groups. The Light Manufacturing Industry has expanded since economic reform in 1978, with the total numbers of enterprises and employees close to, but still lower than those in the Processing Industry. However, due to their high value-added nature, the Light Manufacturing Industry has overtaken the Processing Industry for the industrial sales output value. The High-technology Industry has the highest growth of the numbers of enterprises (288%) and employees (284%) between 1999 and 2007 among the four industrial groups. Its sales output value in 2007 has reached the level that lies between the Processing Industry and the Light Manufacturing Industry. Most importantly, the High-technology Industry has the highest percentage of industrial sales output value designated for export, about three to four times higher than the other three industrial groups. The export share in the Processing Industry output is the second largest, but its share has dropped considerably between the two sample years. Both the Light Manufacturing Industry and the Metal and Machinery Industry show the lowest export potential with mild changes only, suggesting that such outputs are geared mainly for the domestic market.

The regional performance in the sales output value and the numbers of enterprises and employees are similar among the four industrial groups. The Eastern region has the largest shares in the sales output values and the numbers of enterprises and employees. Each of these values in the Eastern region is much larger than the sum of the respective values in the rest three regions. The Eastern region is no doubt the center of the manufacturing industrial production. Between the two sample years, sales output value and the numbers of industrial enterprises and employee have expanded most in the Eastern region, followed by the Southern region. The total number of industrial employees in the weaker Western and Northeastern regions has remained quite static. The Western region is by far the weakest region. In short, the Eastern and Southern regions is the industrial powerhouse in China and their industry output has expanded rapidly in the sample

period. Among the four regions, the Southern region is strongest in terms of export delivery, followed by the Eastern region. The Western region again has the weakest potential for export. Between 1999 and 2007, however, it is only the High-technology Industry that has significantly expanded in the percentage share of value of export, notably in the two richer Eastern and Southern regions. All other industries and regions show either a significant drop or a very mild increase in the performance of export between the two sample years.

By convention, many state-owned enterprises are loss-making and relied on state subsidy. The percentage of loss-making enterprises has declined by half in many cases between 1999 and 2007, especially in the two prosperous Eastern and Southern regions. The Eastern region has the lowest percentage of loss-making enterprises, while the weaker Western region still experiences a large (over 20%) percentage of loss-making enterprises.

In the All China Marketing Research (ACMR) data, the Industrial Output Value at current prices in thousand yuan is the total value of industrial products, whether sold or ready for sales, in a certain period of time. It includes the value of all final products which are warehoused after inspection and packaging, or do not need any further processing. It also includes processing of foreign products, home-made semi-products, and changes in inventories. The Industrial Output Value is calculated with the “factory method”, in which each individual industrial enterprises is regarded as a separate entity, and the final output of all the production activities is considered. This calculation method avoids double counting within the same enterprise.

The total fixed asset investment expressed in thousand yuan shows the enterprise’s value of net fixed assets that includes liquidation of fixed assets, construction in progress, and loss of funds. The operating expenses expressed in thousand yuan refers to expenses of financial firms in the business operation that includes the depreciation of fixed assets, business promotion expenses, business entertainment, electronic equipment running costs, security costs, property insurance companies costs, postal costs, labor protection, foreign fees, printing costs, claims investigation costs, staff wages, travel, utilities, lease costs (excluding finance lease charges), repairs, staff welfare, staff education funds, union funds, real estate tax, travel tax, land tax, stamp duty, meeting fees, legal fees, notary fees, consulting fees, amortization of intangible assets, amortization of long-term prepaid expenses, labor insurance, heating costs, audit fees, technology transfer fees, research and development fees, green fees, the board of directors fees, management fees paid, and advertising.

Studies by Lu (2000), Jefferson (1989) and Chow (1993) have attempted to construct physical capital from individual economic sectors. Both Young (2000, 2003) and Rawski (2002) have pointed out that the inappropriate investment behavior and huge state intervention has distorted allocation of investment resources. Empirical studies have constructed China's national and provincial physical capital and human capital using an inventory approach (e.g. Chow and Li, 2002; Li, 2003, 2009; Liu and Li, 2006; Li *et al.* 2009). In the construction of the physical capital in the study of industry productivity in China, for example, investment figures have reliably been used as a proxy (Jefferson, 1989; Jefferson *et al.*, 1992, 1996; Chen *et al.*, 1988a, 1988b).

Total industrial outputs, deflated by the GDP deflator, are used as the dependent variable in the estimation. The total fixed assets deflated by the investment index are used as the proxy variable for physical capital. Since there is a lack of data on the educational level of industrial workers, a reliable alternative would be wage payments and related labor costs which are included in the operating expenses. Deflated by the GDP deflator, operating expenses is thus used as the proxy for "human capital". The missing 1999-2002 operating expenses data are estimated by interpolation from the 2003-2007 data.

### III Stochastic Frontier Model and Decomposition of Output Growth

The growth of industrial output in the sample period are decomposed into four sources of input growth, adjusted scale effect, technical progress, and technical efficiency change. In theory, the adjusted scale effect shows the returns to scale effect from combined inputs. Technical progress shows the rate of technological change and is indicated by an outward shift in the industry's production possibility frontier. Technical efficiency change refers to a movement from a position within the production possibility frontier towards the production frontier.

The conventional Cobb-Douglas production function shows how a producer maximizes output from inputs. Kumbhakar and Lovell (2000) pointed out that the estimation on output, cost, and profit functions based on the assumption of optimal and efficient operation could produce variation in production efficiency. The stochastic frontier analysis assumes that deviations from the efficient frontier can either be a realization of inefficiency or a random shock (Farrell, 1957; Coelli *et al.*, 1998). The estimation model with a production frontier function without the random component as suggested in Aigner *et al.* (1977) can be stated as:

$$y_i = f(x_i; \beta) \cdot TE_i, \quad (1)$$

where  $y_i$  is the observed scalar output and  $x_i$  is a vector of inputs for  $i^{\text{th}}$  firm,  $\beta$  is a  $k \times 1$  vector of parameters to be estimated and  $TE_i$  denotes the technical efficiency defined as the ratio of observed output to maximum feasible output (Aigner and Chu, 1968). By letting  $y_i = f(x_i; \beta) \exp(-u_i)$ , we then have

$$TE_i = \frac{y_i}{f_i} = \exp(-u_i), \quad (2)$$

where  $u_i$  is supposed to measure technical inefficiency and when  $u_i \geq 0$ , then  $TE \leq 1$  (Battese *et al.*, 2005). Such an output-oriented measure of technical efficiency takes a value between zero and one. It measures the output of the  $i$ -th firm relative to the stochastic frontier output that could be produced by a fully-efficient firm utilizing the same vector of inputs. The technical efficiency  $TE_i$  can be derived using the estimates from the stochastic frontier production model. If  $TE_i = 1$ , then the firm is technically efficient.

The specification of technical inefficiency in Equation (1) might also capture other random shocks that are either beyond the control of the firm or not directly attributable to the underlying technology. The random shocks affecting the production process can be included to the production frontier function by adding a two-sided error term (Aigner and Chu, 1968). The stochastic frontier production now becomes:

$$y_i = f(x_i; \beta) \exp(-u_i) \exp(v_i), \quad (3)$$

where  $\exp(v_i)$  denotes the stochastic component that describes the random shocks. When expressed in a translog production function,  $f(x_i; \beta)$  takes a log-linear form and the stochastic frontier production model can be written as:

$$\ln y_i = \beta_0 + \sum_j \beta_j \ln(x_{ji}) + \sum_k \sum_j \beta_{jk} \ln(x_{ji}) \ln(x_{ki}) + v_i - u_i. \quad (4)$$

The random error,  $v_i$ , is symmetric and normally distributed with  $v_i \sim N(0, \sigma_v^2)$  and the technical inefficiency term,  $u_i$ , is assumed to be a non-negative truncated normal random error with  $u_i \sim N^+(\mu, \sigma_u^2)$ , where  $\mu$  is the mode of the normal distribution (Kumbhakar and Lovell, 2000).

The panel data production function for our empirical estimation is expressed as:

$$\begin{aligned} \ln Y_{it} = & \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_H \ln H_{it} + \beta_{KK} (\ln K_{it})^2 + \beta_{LL} (\ln L_{it})^2 + \beta_{HH} (\ln H_{it})^2 \\ & + \beta_{KL} \ln K_{it} \ln L_{it} + \beta_{KH} \ln K_{it} \ln H_{it} + \beta_{LH} \ln L_{it} \ln H_{it} + \sum_t \delta_t D_t + v_{it} - u_{it} \end{aligned} \quad (5)$$

where  $i=1, \dots, N$  industries and  $t=1, \dots, T$ ;  $\ln Y_{it}$  is the log of real industrial output for  $i^{\text{th}}$  industry at time  $t$ .  $\ln K_{it}$  is the log of total fixed asset investment used as a proxy for physical capital,  $\ln L_{it}$  is the log of total number of employed workers in China,  $\ln H_{it}$  is the log of operating expenses used as a proxy for the human capital variable, and  $D_t$  is the time dummy variable that captures technological progress and the parameter  $\delta_t$  can be used to measure technical level over time.

The technical inefficiency term can either be time variant ( $u_{it}$ ) or time invariant ( $u_i$ ). In the case of time variant technical inefficiency,  $u_{it}$  can be expressed as a monotonic ‘decay’ function as  $u_{it} = \eta_t u_i$ , where  $\eta_t = \exp(-\eta(t-T))$ , and  $\eta$  is an unknown scalar parameter for technical inefficiency.  $u_{it}$  can either be increasing (if  $\eta < 0$ ), decreasing (if  $\eta > 0$ ) or remained constant (if  $\eta = 0$ ) (Battese and Coelli, 1992). The minimum-mean-square-error predictor of the technical efficiency of the  $i^{\text{th}}$  industry at time  $t$  is shown as (Battese and Coelli, 1988, 1992, 1995; Kumbhakar and Lovell, 2000; Coelli, 1996; Battese and Corra, 1977):

$$TE_{it} = E(\exp(-u_{it}) | \mathcal{E}_{it}), \quad (6)$$

where

$$\mathcal{E}_{it} = v_{it} - u_{it}. \quad (7)$$

Using Equations (A11) and (A12) in Appendix B, the decomposition of output growth ( $\dot{Y}_t$ ) for Equation (5) can be represented as follows:

$$\dot{Y}_t = \frac{e_{K_t}}{e_t} \dot{K}_t + \frac{e_{L_t}}{e_t} \dot{L}_t + \frac{e_{H_t}}{e_t} \dot{H}_t + Scale_t + \Delta\delta_t + T\dot{E}_t, \quad (8)$$

$$\dot{Y}_t = \dot{\Phi}_t + Scale_t + \Delta\delta_t + T\dot{E}_t, \quad (9)$$

where  $e_K$ ,  $e_L$ , and  $e_H$  are output elasticities for physical capital, labor, and human capital, respectively;  $e$  is returns to scale;  $\dot{K}$ ,  $\dot{L}$ , and  $\dot{H}$  are growth of inputs, and

$$\dot{\Phi}_t = \frac{e_{K_t}}{e_t} \dot{K}_t + \frac{e_{L_t}}{e_t} \dot{L}_t + \frac{e_{H_t}}{e_t} \dot{H}_t, \quad (10)$$

$$Scale = (e-1)\left(\frac{e_K}{e} \dot{K} + \frac{e_L}{e} \dot{L} + \frac{e_H}{e} \dot{H}\right). \quad (11)$$

Equation (9) indicates that output growth is decomposed into four components. The first term represents the contribution of input growth to the output growth. Equation (A9) in Appendix B shows that the ratio of output elasticity for an input is equal to the cost share of the input. The growth of aggregate input ( $\dot{\Phi}$ ) is the weighted sum of all input growth. The second term is the adjusted scale effect. For increasing returns to scale, the contribution of increasing returns to scale to output growth is positive ( $e-1 > 0$ ), and the scale effect of  $(e-1)$  is adjusted by the growth of aggregate input ( $\dot{\Phi}$ ). For constant returns to scale ( $e=1$ ) or zero input growth ( $\dot{\Phi}=0$ ), the adjusted scale effect is zero. The third term  $\Delta\delta_t = \delta_t - \delta_{t-1}$  is a measure of technical progress and the last term  $T\dot{E}_t$  refers to the change in technical efficiency.

Define the total factor productivity (TFP) for a production function with multiple inputs at time  $t$  as:

$$TFP_t = \frac{Y_t}{\Phi_t}. \quad (12)$$

Then the growth of TFP is:

$$TFP_t = Scale_t + \Delta\delta_t + T\dot{E}_t. \quad (13)$$

The decomposition of output growth and productivity growth, shown in Equations (9) and (13), will be applied to the empirical data. In particular, the components of decomposition can be used to explain the change of output growth over time.

To derive the estimates for the components in the growth and productivity decomposition, we first use the maximum likelihood method to estimate the parameters in Equation (5). The output elasticities for physical capital, labor, and human capital for  $i^{th}$  industry at time  $t$  can be denoted, respectively, as

$$e_{K_{it}} = \beta_K + 2\beta_{KK} \ln K_{it} + \beta_{KL} \ln L_{it} + \beta_{KH} \ln H_{it}, \quad (14)$$

$$e_{L_{it}} = \beta_L + 2\beta_{LL} \ln L_{it} + \beta_{KL} \ln K_{it} + \beta_{LH} \ln H_{it}, \quad (15)$$

$$e_{H_{it}} = \beta_H + 2\beta_{HH} \ln H_{it} + \beta_{KH} \ln K_{it} + \beta_{LH} \ln L_{it}. \quad (16)$$

Substituting the estimated coefficients of  $\beta$ 's in Equation (5) into the above three equations gives  $\hat{e}_{K_{it}}$ ,  $\hat{e}_{L_{it}}$ , and  $\hat{e}_{H_{it}}$ . Then the estimates of three output elasticities for the production

function are estimated by  $\hat{e}_K = \frac{1}{NT} \sum_{i,t} \hat{e}_{K_{it}}$ ,  $\hat{e}_L = \frac{1}{NT} \sum_{i,t} \hat{e}_{L_{it}}$ , and  $\hat{e}_H = \frac{1}{NT} \sum_{i,t} \hat{e}_{H_{it}}$ . The returns to

scale is estimated by  $\hat{e} = \hat{e}_K + \hat{e}_L + \hat{e}_H$ . The estimate of each input growth is simply the sample

mean of the input growth such as  $\hat{K} = \frac{1}{NT} \sum_{i,t} \dot{K}_{it}$ , and so on. The estimates of output elasticities

and individual input growth can be used to estimate the first two components of output growth: growth of aggregate input and adjusted scale effects.

Given the estimated coefficient of  $\delta_t$  in Equation (5), the estimate of technical progress is  $\Delta\delta = \frac{1}{T-1} \sum_t (\hat{\delta}_t - \hat{\delta}_{t-1})$ . Assuming the time-varying decay technical efficiency  $u_{it} = \eta_t u_i$ , where  $\eta_t = \exp(-\eta(t-T))$ , the change in technical efficiency can be estimated by

$$T\dot{E} = \frac{1}{NT} \sum_{i,t} \hat{u}_i \hat{\eta} \exp(-\hat{\eta}(t-T)), \quad (17)$$

where  $\hat{u}$  is the estimate of technical efficiency and  $\hat{\eta}$  is the estimate of time-varying decay parameter. For the time invariant technical efficiency, we have  $\eta_t = 0$  and  $T\dot{E}_t = 0$  for all  $t$ .

#### IV Empirical Results

We apply the stochastic frontier production shown in Equation (5) to the industrial panel data for the sample period 1999-2007. The dependent variable is log real industrial output and the independent variables include the real fixed asset investments (proxy variable for physical capital), employed workers, operating expenses (proxy variable for the human capital), and a total of eight time dummy variables (1999 is the benchmark year) that serve to capture technology progress over time. When the regression includes the industrial data from all provinces, we include three regional dummy variables of Southern, Western, and Northeastern regions, while the Eastern region is regarded as the benchmark.

In estimating technical efficiency, we consider two types of stochastic frontier models: the model with time-varying decay technical inefficiency,  $u_{it} = u_i \exp(-\eta(t-T))$ , and the model with time-invariant technical inefficiency,  $u_{it} = u_i$  for all  $t$ . For the time-invariant technical inefficiency model, the estimate of the change of technical efficiency is zero, namely  $T\dot{E} = 0$ . For the time-varying decay technical inefficiency model, a positive estimate of the time-varying decay parameter  $\mu$  gives positive  $T\dot{E}$  and implies an improvement of technical inefficiency. When we apply the time-varying decay technical inefficiency model to different data sets, the result shows that there are several cases with negative growth in technical efficiency ( $T\dot{E} < 0$ ) for a given data set. We find that a negative growth in technical inefficiency is always accompanied by an unusual large technical progress. However, the sum of estimates of the

technical progress and the growth in technical efficiency ( $\Delta\delta_t + T\dot{E}$ ) is close to the estimate of technical progress for the time-invariant technical inefficiency model. We consider this is an identification problem in the estimation, and we then adopt and use the results from the time-invariant technical inefficiency model.

#### Estimates for the Aggregate, Four Industrial Groups, and 29 Sub-Industries

Table 2 presents the estimates of Equation (5) for the aggregates of all industries and the four groups of manufacturing industries: Processing, Light Manufacturing, Metal and Machinery, and High-technology industrial groups. The first two columns in Table 2 show the estimates for the time-decay variant and time-invariant technical inefficiency models for the aggregates of all industries. In spite of the difference in the use of these two models, most estimated coefficients from these two models are very close. Since the estimate for the time-varying decay parameter  $\eta$  shown in column 1 is not significant, the time-invariant technical inefficiency model shown in column (2) is more appropriate than the time-varying decay technical inefficiency model shown in column (1). For the four industrial groups, we only find that the High-technology Industry has the time-varying decay technical inefficiency property, as shown in column (6). The estimated coefficient of the time-varying decay parameter ( $\eta$ ) for the High-technology Industry is 0.034, which indicates an improvement in technical efficiency. The rest of the three columns for the other three industrial groups contain the estimates from the time-invariant of technical inefficiency model.

Table 2 shows that almost all estimated coefficients of the inputs (physical capital, labor, and human capital) are significant at 5% level. We apply the  $\chi^2$  test for the significance of the six nonlinear terms,  $(\ln K)^2$ ,  $(\ln L)^2$ ,  $(\ln H)^2$ ,  $\ln K \times \ln L$ ,  $\ln K \times \ln H$ ,  $\ln L \times \ln H$ . The test statistics  $\chi^2(nonlinear)$  in Table 2 are all significant and show that the translog function is more appropriate than the Cobb-Douglas function for the aggregates and all four industrial groups. Because of the nonlinear relationship in the translog function, the relationship between inputs and output should best be described by the output elasticities shown in Table 3. Table 2 shows that the estimated coefficients of regional dummies are all negative and significant. The  $\chi^2$  tests for the joint hypothesis test of all regional dummy variables,  $\chi^2(regions)$ , are all significant as well. This implies that the output growths for the Southern, Northeastern, and Western regions

are all smaller than the growth in the Eastern region. The coefficient for the Western region is the smallest, suggesting that the Western region has the slowest growth rate and its growth is about 0.5% lower than the Eastern region. The estimated coefficients for the time dummy variables are not shown in the table, only the joint hypothesis tests for the coefficients of time dummy variables  $\chi^2 (time)$  are displayed in Table 2. All the test statistics are significant at 5% level for the aggregates and industrial groups, except for the High-technology Industry. The p-value of the  $\chi^2 (time)$  test for the High-technology Industry is 5.6%. The technical progress estimates may not be significant for the High-technology Industry.

Equations (9) and (13) show the decomposition of output growth ( $\dot{Y}$ ) and total factor productivity growth ( $\dot{TFP}$ ). To estimate the components of output and productivity growth, we derive the estimates for the output elasticity with respect to the three inputs of capital, labor and human capital ( $e_K$ ,  $e_L$  and  $e_H$ , respectively), the returns to scale ( $e$ ), the adjusted scale effect ( $Scale$ ), the rate of technical progress ( $\Delta\delta_t$ ), and the growth of technical inefficiency ( $\dot{TE}$ ). Table 3 shows these estimates for the industry aggregates and the four industrial groups. Note that the estimates for the industry aggregates and the three industrial groups are based on the model with time invariant technical efficiency and  $\dot{TE} = 0$ ; only the estimates for the High-technology Industry are from the model with time-varying decay technical efficiency.

A number of observations can be made from Table 3. For the aggregates of all industries, the output elasticity for labor (0.617) is the largest, followed by human capital and physical capital (0.501 and 0.335, respectively). The estimates of these three elasticities in four industrial groups are similar to those for the aggregates; the output elasticities for labor (between 0.601 and 0.658) are the largest, then followed by the output elasticities for human capital (between 0.427 and 0.558) and the output elasticities for physical capital (between 0.311 and 0.372). The sum of three output elasticities for the aggregates and four industrial groups are all greater than one, which implies increasing returns to scale. The returns to scale for the aggregates are 1.453; the returns of scale for four industrial groups have a range from the Light Manufacturing Industry's 1.386 to the High-technology Industry's 1.527. These increasing returns to scale suggest positive adjusted scale effects.

For the aggregates of all industries, labor has the largest cost share (42.5%) followed by human capital and physical capital (34.5% and 23.1%, respectively). For the four industrial

groups, the cost shares for the three inputs are similar to those in the aggregates. For the cost share of labor, the Light Manufacturing Industry has the largest share of 44.6%. For human capital, the High-technology Industry has the largest share of 36.5%. For physical capital, the Processing Industry has the largest share of 26.5%. These cost shares are in line with expectations given the labor-intensive and capital-intensive nature of different industrial groups.

The aggregate input growth for the aggregates of all industries is 6.89%. Among the three inputs, human capital growth is the fastest with 3.39%, while the growth for physical capital and labor are 2.0% and 1.5%, respectively. Due to the positive input growth and the increasing returns to scale, the adjusted scale effect contributes 3.08% to output growth. For the four industrial groups, the High-technology Industry has experienced the largest input growth (8.37%), followed by the Metal and Machinery industry (7.2%), the Light Manufacturing Industry (7.07%), and the Processing Industry (5.17%). The high input growth in both High-technology Industry and Metal and Machinery Industry is due mainly to the growth in human capital. The low input growth for Processing Industry is because of low labor input growth. With the high input growth and increasing return to scale, the High-technology Industry has the highest adjusted scale effect (4.35%). The input growth for Light Manufacturing Industry and Metal and Machinery Industry are similar, the adjusted scale effect for the Metal and Machinery Industry is higher since it has a higher returns to scale. The Processing Industry has the lowest adjusted scale effect, which is mainly caused by the low input growth.

Based on the test statistics of the time-varying decay parameter, we find that the aggregates of all industries and three industrial groups have no changes in technical efficiency, namely  $TE = 0$ . It is only the High-technology Industry that shows a positive improvement of technical efficiency (6.92%) and its technical progress is close to zero (0.92%). For the aggregates of all industries, input growth explains about 38% of output growth (6.89% of 18.07%), technical progress explains about 45% of total output growth (8.1% out of 18.07%), adjusted scale effect explains the rest 17% of output growth. The total factor productivity, which is the sum of the adjusted scale effect and technical progress, contributes about 62% to total output growth. For the four industrial groups, the Metal and Machinery Industry and the High-technology Industry have higher output growth than the other two industrial groups (19.83% and 20.56% vs. 14.63% and 16.95%). Among the four industrial groups, the Metal and Machinery Industry has the highest rate of technological progress (9.36%) and the highest growth of TFP

(12.71%), reflecting the continued importance of the conventional heavy industry. The high output growth for the High-technology Industry can be explained by high input growth (8.37%) and adjusted scale effects (4.35%), which are higher than those for the other three industrial groups. Both the Metal and Machinery Industry and High-technology Industry have a higher TFP growth than the other two industrial groups (12.71% and 12.19% vs. 9.46% and 9.88%). The absolute values of the errors between the estimated output growth and the actual output growth are all less than 1%.

Tables 2 and 3 consider the four key industrial groups based on a total of 161 three-digit industries, as summarized in Table A1 in Appendix A. Alternatively, these 161 three-digit industries can be aggregated into 29 sub-industries. For example, the Processing Industry contains 53 three-digit industries between the codes 131 and 195. Among these industries, the industries between 131 and 139 are aggregated into one industry with the code of “13”; the industries between 140 and 149 are aggregated into the industry with the code of “14”, and so on. The industries with a code from 13 to 19, 20 to 29, 30 to 37 and 40 to 43 belong to Processing Industry, Light Manufacturing Industry, Metal and Machinery Industry and High-technology Industry, respectively. The estimates of growth decomposition for each of these 29 two-digit industries shown in Table 4 provide a detailed view of the manufacturing industries. The observations from Table 4 can be summarized as follows.

Due probably to deliberate policy on health hazards the tobacco processing industry (code #16) has an unusual low growth of 3.83%. The two unusual high output growth industries are the oil industry (code #25) and the metal smelting and alloys industry (code #33), with growth rates of 27.69% and 30.95%, respectively. The high output growth for these two industries is mainly due to technical progress, and the high demand for energy and metal products. If we remove these three industries as outliers, the growth from the remaining 26 industries still has a large variation, ranging from 8.95% to 24.12%.

The large variation of output growth is common for the industries in each of the four key industrial groups. The high variation of output growth is accompanied by high variation in input growth, scale effect, and the combined effect of the technical progress and the change in technical efficiency. Industry input growth has an average of 6.77% and ranges from 1.65% to 11.94%. The returns to scale show an average of 2.88% and a range from 0.58% to 5.06%. The combined effect of the technological progress and the change in the technical efficiency shows

an average of 7.77%, higher than the input growth, but the range is large from 2.65% to 14.23% (excluding industry codes #16, #25, and #33).

For the input growth, except the four industries in High-technology Industry, the industries in the rest three key industrial groups have large variation of input growth. The input growth for all industries in the Processing Industry are lower than 8% while the input growth for all four industries in the High-technology Industry are more than 8%. For the adjusted scale effect, the industries in the Processing Industry and the Light Manufacturing Industry have a larger variation than the industries in the Metal and Machinery Industry and the High-technology Industry, which all have an adjusted scale effect of higher than 2%.

With the exception of five industries (codes # 15, 34, 40, 41 and 42), there is an absence of technical efficiency change in the majority of industries. Among the five industries with technical efficiency change, the High-technology Industry is the only industry group that has enjoyed improvement in efficiency. In the performance of TFP growth, all but three industries enjoyed a growth rate in excess of 8%, with two close to 20%. Most industries in the Metal and Machinery Industry and the High-technology Industry have the growth of TFP more than 10% and most industries in the rest two key industries have the growth less than 10%. Five industries have an absolute estimation error between the actual output growth and estimated output growth greater than 1% and all other 24 industries have an error less than 1%.

Our empirical results for the manufacturing industries show that the output growth can be explained by input growth, adjusted scale effect, technical progress, and the change in technical efficiency. For the aggregates of all industries, input growth explains 38%, adjusted scale effect explains 17%, and technical progress explains 45% of output growth, but there is no evidence of technical efficiency change. As shown in Young (2000, 2003) and Li (2009), China's post-reform GDP growth has depended largely on capital inputs. Our results show that technical progress is more important than input growth for manufacturing industries. Furthermore, increasing returns to scale plays an important role for the industrial output growth. Traditionally, the contribution from the scale effect has been ignored. Mathematically, the scale effect is a part of the growth of total factor productivity. We found that scale effect explains about 27% of the growth of TFP (17% out of 62%). Among the three inputs included in the production function, our results show human capital contributes about one-half of total input growth and the contribution from physical capital has surpassed the contribution from labor. Despite the large

labor force, recent studies (Fleisher *et al.*, 2009; Li *et al.*, 2009) show that human capital has been lacking, especially in the middle-management range. Our results indicate that the manufacturing industries do attract the formation and the growth of human capital.

In general, the industries in the Metal and Machinery Industry and the High-technology Industry have a higher output growth than the industries in the Processing Industry and the Light Manufacturing Industry due to both high input growth and high TFP growth. This shows that the process of industrialization that transforms light industries to heavy and technology-intensive industries is evident in our sample period. The high input growth for the High-technology Industry is related to the growth of labor and human capital; the high input growth for the Metal and Machinery Industry is related to the growth of physical capital and human capital. This suggests that the labor movement from light industries to heavy and technology-intensive industries is also accompanied by the growth of human capital, especially in the High-technology Industry. Most industries in the High-technology Industry contain newly formed business and industries, which induces the high demand for the labor force and high labor growth. The low labor growth for the Metal and Machinery Industry is mainly because of certain types of heavy industries. The growth of these heavy industries requires more physical capital and human capital than labor.

For all four key industrial groups and 29 sub-industries, we only find the improvement of technical efficiency in the High-technical Industry and five sub-industries, three of them are in the High-technical Industry. The lack of the improvement in technical efficiency for most industries may not be an issue for economic growth. Figure 1 shows two extreme cases of output growth. Figure 1A represents the growth without the improvement of technical efficiency. In this figure, there are two production functions  $F_1$  and  $F_2$  at time 1 and time 2, respectively. The shift from  $F_1$  to  $F_2$  represents technical progress. Suppose the output at time 1 is point A and the output at time 2 is point C. The distance AB is the technical inefficiency at time 1 and the distance CD is the technical inefficiency at time 2. There is no change in the technical inefficiency when  $AB = CD$ . Figure 1B is similar to Figure 1A, except that there is only one production function. The output at time 1 is A and the output at time 2 is C. Therefore, the technical inefficiency at time 1 is AB and the technical inefficiency at time 2 is CD. In this figure, there is no technical progress. However, the technical inefficiency is reduced from AB to CD. The concern for the growth in Figure 1A is the lack of technical efficiency improvement and the

concern for Figure 1B is the lack of technical progress. Both Figure 1A and 1B show the same output growth from A to C, but these two types of economic growth could have different economic implications. We can conjecture that the growth of a mature industry could be similar to Figure 1A; the growth of a newly formed industry could be similar to Figure 1B. This conjecture is consistent to our results where the High-technology Industry is more of a new industry.

Comparing to a small variation in the output growth for the four key industrial groups, it is not surprising to see a large variation in the output growth for the 29 sub-industries because of their heterogeneous products. The larger variation of output growth for the 29 sub-industries represents a flexibility of production in a market economy. In contrast to the production in a planned economy, the output growth for each manufacturing industry is basically driven by the market demand and supply for that typical product. However, the high industrial output growth with an average of 18% could be of concerned. For example, can the growth of 28% in the oil industry and the growth of 31% in the metal smelting and alloys industry continue for the next decade? Empirically, the concern for the unusual high output growth in the manufacturing industries has formidably been discussed in Szirmai *et al.* (2005) and Maddison and Wu (2008) on the possible inflated industrial output. This paper does not address these concerns, but instead checks the sources of output growth assuming that the data are empirically reliable.

### Regional and Provincial Analysis

The output growth of industrial output may vary in different regions in China because of their difference in historical background and economic development. Using growth decomposition, we can examine the difference in the sources of output growth due to regional difference. We first apply the stochastic frontier model to the data set from each of four key industrial groups and each region. And we try both time-varying decay and time-invariant technical inefficient models to each data set. We pick the result with a better fit from the two models. Table 5 shows only the estimates of the chosen model for the four industrial groups in the four regions. For those data set with time-invariant technical inefficiency, the estimate of change in the technical efficiency is zero with  $\dot{TE} = 0$ . The observations from Table 5 can be summarized as follows.

For the Processing Industry, none of the regions exhibit time-varying decay technical inefficiency. The Southern and Northeastern regions have higher estimated output growth than the other two regions. The Southern region's high output growth is due to high input growth (7.32%) and scale effect (4.0%). Both the Northeastern and Western regions have high technical progress (10.82% and 10.15%, respectively) that is about twice the size of the other two regions. For the Light Manufacturing Industry, the Southern region shows an improvement in technical efficiency of 3.74%. However, the sum of its technical progress (2.54%) and the change in the technical efficiency is still less than the national rate of technical progress of 7.17%. The output growth rates in both Southern and Northeastern regions are greater than the other two regions. The high growth in the Southern region is caused by high input growth (9.41%) and scale effect (4.07%). The high growth in the Northeastern region is due to high input growth (7.92%) and technical progress (9.09%).

The Metal and Machinery Industry has the highest estimated output growth in the Southern and Northeastern regions. The high output growth in the Southern region is due to high input growth (9.15%) and scale effect (4.18%); the high output growth in the Northeastern region is due to high total factor productivity (14.78%), including 2.77% of the improvement in technical efficiency. The technical progress in four regions is relatively close, and has the smallest variation comparing to other three industrial groups. The imbalanced regional growth for the Metal and Machinery Industry is mainly caused by the difference in input growth.

The High-technology Industry has the highest overall output growth among four industrial groups, especially in the Eastern, Southern, and Western regions. The high growth in the Southern region is mainly due to high input growth (9.45%); the high growth in the other two regions is due to a high total factor productivity growth, which is more than 12%. Both the Eastern and Western regions show positive change in the technical efficiency (6.12% and 6.09%, respectively). The Northeastern region has the lowest growth, probably due to low input growth and a small adjusted scale effect, although it has the highest technical progress (9.06%) among the four regions. The absolute values of the errors between actual output growth and estimated output growth for all four industrial groups in the four different regions are less than 1%, with the exception for the Processing Industry in the Western region (-1.26%).

Table 6 shows the growth decomposition based on individual provinces among the four regions. The Southern and Northeast regions (20.58% and 19.28%, respectively) have higher

growth than the Eastern and Western regions (16.74% and 16.53%, respectively). This result is consistent with the results of the regional analysis for the four industrial groups in Table 5. The high growth in the Southern region is mainly due to the input growth (8.82%) and the high growth in the Northeastern is due to technical progress (10.11%). The Western region has a low output growth due to low input growth (4.88%). However, its technical growth (9.22%) is the second largest in the four regions. As far as the Eastern provinces are concerned, Beijing, being the capital, has a lowest estimated output growth, while the strong growth provinces are the new industrial areas of Shandong, Anhui and Zhejiang, which are supported by large input growth. On the contrary, Henan has the highest technology progress among all provinces. Technical efficiency change appeared strongly only in Hubei (5.2%) and mildly in Hebei (1.25%) provinces. Among the provinces in the Southern region, five provinces (Fujian, Jiangxi, Hunan, Chongqing, and Sichuan) have an output growth higher than 20%. Again, input growth provides the explanation to their strong output growth. The province of Hunan (6.25%) experiences a high level of technical efficiency change, followed by Jiangxi (1.53%) with a much milder change.

Among eight provinces with a high output growth in the Eastern and Southern regions, only two provinces (Zhejiang and Fujian) are coastal provinces. Other coastal provinces, including Guangdong, Tianjin, Hebei, and Shanghai, probably are more of business, finance, and services provinces and focus on exporting. The first wave of economic growth after the open door policy in 1978 started from the coastal provinces. The high manufacturing output growth for the inner provinces indicates a second wave of the industrial development in China. The high growth of the inner provinces may have two implications. First, the manufacturing production for export has gradually moved from the coastal provinces to the inner provinces because of their lower labor wage and land use cost. Second, the high economic growth in China in the past three decade has induced the growth of domestic demand. The manufacturing production in the inner provinces is to satisfy the huge domestic market demand. Sichuan with a leading output growth is an example of the expansion of domestic demand.

The output growth rates among provinces in the Western regions are close to each other, except Tibet that is too remote for any industrial development, and Mongolia and Ningxia that show a much stronger performance than all other provinces. The output growth for individual provinces in the Western region is comparable to the provinces in the Eastern region due to their high technical progress, despite the general weakness in their remoteness. Among the three

provinces in the Northeast region, Jilin and Liaoning show a better performance in output growth and technical efficiency change. The most northern Heilongjiang province shows a weaker performance.

## V Conclusion

Armed with over three decades of economic reform since 1978, China's industrial exports by the turn of the 21<sup>st</sup> century have captured world attention. This paper acknowledges the potential data problem and investigates into the factors that contribute to industrial output growth in different industrial groups and geographical regions in China. The empirical findings do provide an "X-ray" on industrial performance in China by identifying its strengths that show the various potentials and weaknesses that require additional improvements. There are lessons China can learn from Japan, for example, whose experience in the 1970s showed that qualitative products counted a lot in conquering the world export market. Having achieved a high level of cheap labor-intensive manufacturing export, China should look into her next stage of industrial development if exports, especially in the high-end products, were to continue to provide overall economy vigor to economic development in China.

By using the more recent manufacturing industrial data and the appropriate proxy variables on physical capital and human capital, this paper conducts a comprehensive study on the growth and productivity attributes for four key industrial groups, 29 sub-industries, and 31 provinces in four regions. Our growth decomposition method and regression results estimate the contributions from inputs, scale effect, technical progress, and technical efficiency changes to output growth. We found that labor has the largest cost share in the production, but its contribution to the input growth is the lowest, implying possibly the end of a low labor cost era in China's manufacturing. Human capital contributes about one-half of total input growth due to the large number of graduates from tertiary institutions. In terms of the total output elasticity, the three inputs generate increasing returns to scale. This results in a positive scale effect for all the four groups of manufacturing industries, 29 sub-industries and 31 provinces. It contributes about 27% of the growth of total factor productivity.

Technical progress has contributed mostly in all four industry groups. The Metal and Machinery Industry has achieved the highest technical progress, while the High-technology Industry has lacked behind. However, the High-technology Industry dominates input growth due

to a high input growth effect for labor and human capital. Both the Metal and Machinery Industry and the High-technology Industry have higher TFP growth than the Processing Industry and the Light Manufacturing Industry. All four industrial groups have the highest growth in the Southern region due to high input growth and scale effect. The output growth in the Northeastern region is also high and is close to that for the Southern region for all four industrial groups, except the High-technology Industry. The high output growth in the Northeastern region is due to technical progress and the change in technical efficiency. The High-technology Industry has a high growth in the Western region because of high TFP growth.

Other than the performance of individual industry group and region, the macro picture is that China's industrial strength is based mainly in input growth, and the subsequent improvement in technical progress. These two factors probably explain the high quantity of Chinese manufacturing output and exports. The next challenge to industrial development in China will be the quality end, including efficiency change and promotion, and the appropriate development in human capital, in addition to other existing problems, such regional imbalance. Nonetheless, one has to take into account that China has gone far in the last three decades of reform, and the question is how China can extend its industrial and economic development qualitatively and comprehensively.

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## Appendix A: Data Description

Table A1 The Four Groups of Manufacturing Industries in China

|          |                                                                                                                                                                                                                                                                                                                                                                                     |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.       | Processing Industry                                                                                                                                                                                                                                                                                                                                                                 |
| 131-139  | Food and feed processing industry; Seed fat processing industry; Sugar industry; Slaughtering, meat and eggs processing industries; Aquatic products processing industry; Salt industry, and other food processing industry.                                                                                                                                                        |
| 141- 149 | Cakes, candy manufacturing; Dairy manufacturing; Canned food manufacturing; Fermentation products industry; Condiment manufacturing; and Other food manufacturing.                                                                                                                                                                                                                  |
| 151- 159 | Alcohol and alcohol beverage manufacturing sector; Soft drink manufacturing; Tea industry, and other beverage manufacturing.                                                                                                                                                                                                                                                        |
| 161-169  | Cured tobacco industry; Cigarette manufacturing, and other tobacco processing industry.                                                                                                                                                                                                                                                                                             |
| 172-183  | Cotton textile industry; Cotton textile industry; Wool textile industry, bast fibre manufacturing; Silk textiles; Knitwear industry; Other textiles; Apparel manufacturing; Hat industry; Shoemaking, and other fiber products industry.                                                                                                                                            |
| 191-195  | Light leather industry; Leather products manufacturing; Tanning and fur industry; and Feather (down) and products industry.                                                                                                                                                                                                                                                         |
| 2.       | Light Manufacturing Industry                                                                                                                                                                                                                                                                                                                                                        |
| 201- 204 | Sawn timber, wood processing industry; Wood-based panel manufacturing; Wood products industry; and Bamboo, rattan, palm and grass products industry.                                                                                                                                                                                                                                |
| 211-219  | Wood furniture manufacturing; Bamboo, rattan furniture manufacturing industry; Metal furniture manufacturing; Plastic furniture manufacturing, and other furniture manufacturing.                                                                                                                                                                                                   |
| 221-223  | Pulp manufacturing; Paper; and Paper products industry.                                                                                                                                                                                                                                                                                                                             |
| 231-232  | Printing industry; and Reproduction of recorded media.                                                                                                                                                                                                                                                                                                                              |
| 241-249  | Stationery Manufacturing; Sporting goods manufacturing; Musical instruments and other cultural goods industry; Toys manufacturing; Recreation equipment manufacturing, and other types of culture and education are not included in the sporting goods manufacturing.                                                                                                               |
| 251-257  | Synthetic crude oil production industry; Crude oil processing industry; Petroleum products industry; and Coking industry.                                                                                                                                                                                                                                                           |
| 261-268  | Basic chemical raw materials manufacturing industry; Chemical fertilizer manufacturing; Chemical pesticides manufacturing; Organic chemical products manufacturing; Synthetic materials manufacturing; Special chemical products manufacturing; and Daily-use chemical products manufacturing.                                                                                      |
| 271- 275 | Chemicals manufacturing TC; Manufacturing chemical agents; Chinese herbal medicines and proprietary Chinese medicine industry; Animal drug manufacturing; and Biological products industry.                                                                                                                                                                                         |
| 281-285  | Cellulose fiber manufacturing; Synthetic fiber manufacturing industry; and Fishing gear and fishing gear materials manufacturing.                                                                                                                                                                                                                                                   |
| 291-299  | Tire manufacturing, hand cart tire manufacturing; Rubber board, tube, with the manufacturing sector; Rubber parts products industry; Reclaimed rubber manufacturing, gumboot manufacturing; Daily-use the rubber products industry; Renovation industry rubber, and other rubber products industry.                                                                                 |
| 3.       | Metal and Machinery Industry                                                                                                                                                                                                                                                                                                                                                        |
| 301-309  | Plastic film manufacturing; Plastic plates, pipes, rods manufacturing; Plastic wire, rope and woven goods manufacturing; Foam and leather, synthetic leather manufacturing; Plastic packaging and containers manufacturing; Plastic shoes manufacturing; Daily-use sundry goods manufacturing plastics; Plastic parts and components industry, and other plastic products industry. |
| 311-319  | Cement manufacturing; Cement products and asbestos-cement products industry; Brick, lime and light manufacturing building materials; Glass and glass products industry; Ceramic products; Refractory products industry; Graphite and carbon products industry; and Mineral fibers and products industry not covered by other types of non-metallic mineral products industry.       |
| 321-326  | Iron & Steel industry; Steel rolling processing industry; and Ferroalloy smelting industry.                                                                                                                                                                                                                                                                                         |
| 331-336  | Heavy non-ferrous metal smelting industry; Light non-ferrous metal smelting industry; and Non-ferrous alloys industry.                                                                                                                                                                                                                                                              |
| 341-349  | Manufacturing of metal structures; Cast iron pipe manufacturing; Tool manufacturing; Metal                                                                                                                                                                                                                                                                                          |

containers and packaging materials manufacturing, wirework & wirework industry; Fabricated metal products used in construction; Metal surface treatment and heat treatment industry; Ceramic manufacturing, and other fabricated metal products.

351-359 Boiler and prime mover manufacturing; Metalworking machinery manufacturing; General equipment manufacturing; Bearings, valves manufacturing; Other common parts manufacturing; Castings and forgings manufacturing; General mechanical repair industry, and other general machinery manufacturing.

361-368 Metallurgy, mining, mechanical and electrical equipment manufacturing industry; Petrochemical and other industrial equipment manufacturing; Textile industry equipment manufacturing; Agriculture, forestry, animal husbandry and fishery, water conservancy industry machinery manufacturing; Medical equipment manufacturing; Special equipment manufacturing industry; and Industry-specific machinery and equipment repair.

371-379 Railway transportation equipment manufacturing; Automotive; Motorcycle manufacturing; Bicycle manufacturing; Tram manufacturing; Ship manufacturing; Repair of transportation equipment industry, and other transportation equipment manufacturing industry.

#### 4. High-technology Industry

401- 409 Motor manufacturing industry; Transmission and distribution and control equipment manufacturing; Electrical equipment manufacturing; Household electrical appliances manufacturing; Lighting equipment manufacturing; Repair of electrical machinery industry, and other electrical machinery manufacturing industry.

411-419 Communications equipment manufacturing; Radio and television equipment manufacturing industry; Electronic computer manufacturing; Electronics manufacturing; Electronic components manufacturing; Daily-use electronic equipment manufacturing; Electronic devices and communications equipment repair industry, and other electronic equipment manufacturing.

421-429 Universal instruments manufacturing; Dedicated instrumentation manufacturing; Manufacturing of electronic measurement instruments; Measuring equipment manufacturing; Culture, office machinery manufacturing; Manufacture of watches; Instrumentation and culture, office equipment repair industry, and other instrumentation manufacturing.

431-439 Arts and crafts manufacturing; Daily-use sundry goods manufacturing; and Other supplies manufacturing.

Source: *Support System for China Statistical Application*, All China Marketing Research (ACMR), Beijing (<http://info.acmr.cn>).

Table A2 Number of Observations

|                     | East   | South | West  | Northeast | Total  |
|---------------------|--------|-------|-------|-----------|--------|
| Processing          | 2,628  | 1,744 | 1,216 | 645       | 6,233  |
| Light Manufacturing | 3,671  | 2,232 | 1,311 | 814       | 8,028  |
| Metal and Machinery | 5,028  | 3,166 | 2,253 | 1,245     | 11,692 |
| High-Technology     | 1,965  | 1,068 | 424   | 402       | 3,859  |
| Total               | 13,292 | 8,210 | 5,204 | 3,106     | 29,812 |

Note: The number of observations is based on 161 three-digit industries in 31 provinces from 1999 to 2007, excluding missing observations.

## Appendix B. Growth Decomposition

Suppose the production at time  $t$  has the following form.

$$Y_t = F(X_{1t}, X_{2t}, \dots, X_{nt}, t) e^{-u_t}, \quad (A1)$$

where  $Y_t$  is output and  $X_{jt}$  is the inputs,  $j = 1, 2, \dots, n$ . The last term  $e^{-u_t}$  measures technical inefficiency. Taking logarithm-differentiation of (A1) with respect to time, it gives

$$\dot{Y}_t = \sum_j \frac{\partial F}{\partial X_{jt}} \frac{X_{jt}}{F} \dot{X}_{jt} + \frac{\partial F / \partial t}{F} - \frac{\partial u_t}{\partial t}, \quad (A2)$$

where  $\dot{Y}_t = \frac{\partial Y_t / \partial t}{Y_t}$  is the growth of output and  $\dot{X}_{jt} = \frac{\partial X_{jt} / \partial t}{X_{jt}}$  is the growth of input  $X_{jt}$ . Denote

technical progress as  $\dot{A}_t = \frac{\partial F / \partial t}{F}$ . Define the technical efficiency ( $TE$ ) as the ratio of the actual

output and the potential output,  $TE_t = \frac{Y}{F} = e^{-u_t}$ . Then, the growth of the technical efficiency  $\dot{TE}_t$

is  $\dot{TE}_t = -\frac{\partial u_t}{\partial t}$ . Denote  $e_{jt} = \frac{\partial F}{\partial X_{jt}} \frac{X_{jt}}{F}$  as the output elasticity with respect to input  $X_{jt}$ . The output growth can be represented as

$$\dot{Y}_t = \sum_j e_{jt} \dot{X}_{jt} + \dot{A}_t + \dot{TE}_t. \quad (A3)$$

Consider the cost minimization problem of the objective function:  $\min_{X_{jt}} C_t$ , where  $C_t = \sum_j w_{jt} X_{jt}$ , subject to the constraint of (A1). In the Lagrangian form, the objective function and the constraint are written as:

$$L(X_{jt}, \lambda) = \sum_j w_{jt} X_{jt} + \lambda (Y_t - F e^{-u_t}), \quad (A4)$$

where  $\lambda$  is the Lagrange multiplier. The first-order condition for minimization is

$$w_{jt} = \lambda \frac{\partial F}{\partial X_{jt}} e^{-u_t}. \quad (A5)$$

Multiplying both side by  $X_{jt}$ ,

$$w_{jt} X_{jt} = \lambda \frac{\partial F}{\partial X_{jt}} X_{jt} e^{-u_t} = \lambda \frac{\partial F}{\partial X_{jt}} \frac{X_{jt}}{F} F e^{-u_t} = \lambda e_{jt} Y_t, \quad (A6)$$

Taking the sum for all input, the total cost  $C_t$  is

$$C_t = \sum_j w_{jt} X_{jt} = \sum_j \lambda e_{jt} Y_t = \lambda e_t Y_t, \quad (\text{A7})$$

where  $e_t = \sum_j e_{jt}$  is the sum of output elasticities to input. It can be shown that  $e_t$  is a measure of returns to scale. Suppose changes in all inputs have the same scale,  $\Delta X_{jt} = a X_{jt}$ . Consider the changes in output  $\Delta F$  by taking the total derivative of  $F(X_1, X_2, \dots, X_n, t)$  and substituting  $\Delta X_{jt} = a X_{jt}$  into  $\Delta F$ , we have

$$\begin{aligned} \Delta F &= \sum_j \frac{\partial F}{\partial X_{jt}} \Delta X_{jt} + \frac{\partial F}{\partial t} \Delta t = F \sum_j \frac{\partial F}{\partial X_{jt}} \frac{a X_{jt}}{F} + F \dot{A}_t = F a \sum_j e_{jt} + F \dot{A}_t \\ &= a F e_t + F \dot{A}_t. \end{aligned} \quad (\text{A8})$$

The production shows increasing (constant, decreasing) returns to scale when  $e_t > 1$  ( $= 1$ ,  $< 1$ ). Dividing (A5) by (A7), the cost share is

$$s_{jt} = \frac{w_{jt} X_{jt}}{C_t} = \frac{e_{jt}}{e_t}. \quad (\text{A9})$$

This shows that the cost share is always equal to the relative output elasticity in the case of cost minimization. We can rewrite the output growth Equation (A3) as

$$\dot{Y}_t = e_t \sum_j \frac{e_{jt}}{e_t} \dot{X}_{jt} + \dot{A}_t + T \dot{E}_t. \quad (\text{A10})$$

By adding and subtracting term,

$$\dot{Y}_t = \sum_j \frac{e_{jt}}{e_t} \dot{X}_{jt} + (e_t - 1) \sum_j \frac{e_{jt}}{e_t} \dot{X}_{jt} + \dot{A}_t + T \dot{E}_t. \quad (\text{A11})$$

Using the cost share Equation (A9),

$$\dot{Y}_t = \sum_j s_{jt} \dot{X}_{jt} + (e_t - 1) \sum_j s_{jt} \dot{X}_{jt} + \dot{A}_t + T \dot{E}_t. \quad (\text{A12})$$

In the above, the output growth is decomposed into four sources: input growth  $\dot{\Phi}_t = \sum_j s_{jt} \dot{X}_{jt}$ , adjusted scale effect  $(e_t - 1) \dot{\Phi}_t$ , technical progress  $\dot{A}_t$ , and the growth of technical efficiency  $T \dot{E}_t$ .

Table 1 Performance of Industries in the Four Regions China: 1999 and 2007

| <u>Industry / Region</u> | Total No. of Enterprises |         | Total No. of Employees (10,000) |       | Industrial Sales Output Value (Million 2,000 yuan) |        | % of Value of Export Delivery |       | % of Loss-making Enterprises |       |
|--------------------------|--------------------------|---------|---------------------------------|-------|----------------------------------------------------|--------|-------------------------------|-------|------------------------------|-------|
|                          | 1999                     | 2007    | 1999                            | 2007  | 1999                                               | 2007   | 1999                          | 2007  | 1999                         | 2007  |
| All Industries           | 139,080                  | 303,513 | 4,241                           | 6,669 | 5,743                                              | 27,131 | 18.49                         | 21.13 | 27.30                        | 13.49 |
| Processing               | 39,919                   | 77,844  | 1,188                           | 1,804 | 1,475                                              | 4,998  | 24.27                         | 18.41 | 29.80                        | 13.41 |
| Eastern                  | 23,666                   | 50,747  | 716                             | 1,075 | 904                                                | 3,141  | 23.67                         | 18.78 | 24.16                        | 12.43 |
| Southern                 | 10,525                   | 19,513  | 310                             | 565   | 391                                                | 1,260  | 31.97                         | 21.98 | 36.56                        | 13.92 |
| Western                  | 3,113                    | 2,946   | 82                              | 76    | 103                                                | 268    | 5.83                          | 4.10  | 42.92                        | 22.74 |
| Northeastern             | 2,615                    | 4,638   | 80                              | 88    | 77                                                 | 329    | 16.88                         | 12.77 | 38.01                        | 16.00 |
| Light Manufacturing      | 32,002                   | 64,157  | 906                             | 1,231 | 1,315                                              | 5,925  | 11.63                         | 11.14 | 25.80                        | 14.37 |
| Eastern                  | 18,692                   | 38,172  | 528                             | 677   | 808                                                | 3,657  | 10.40                         | 11.05 | 20.00                        | 12.21 |
| Southern                 | 8,361                    | 18,367  | 219                             | 379   | 293                                                | 1,288  | 19.11                         | 15.53 | 32.78                        | 14.93 |
| Western                  | 2,519                    | 2,979   | 67                              | 82    | 74                                                 | 367    | 4.05                          | 3.00  | 36.92                        | 33.23 |
| Northeastern             | 2,430                    | 4,639   | 92                              | 93    | 140                                                | 613    | 7.14                          | 7.34  | 34.94                        | 17.81 |
| Metal & Machinery        | 53,310                   | 121,607 | 1,706                           | 2,380 | 1,933                                              | 10,750 | 12.11                         | 12.64 | 26.58                        | 12.57 |
| Eastern                  | 32,697                   | 76,870  | 986                             | 1,371 | 1,246                                              | 6,763  | 10.19                         | 12.05 | 21.01                        | 10.74 |
| Southern                 | 12,924                   | 31,123  | 397                             | 680   | 432                                                | 2,490  | 20.14                         | 16.47 | 35.75                        | 13.73 |
| Western                  | 3,778                    | 4,332   | 135                             | 135   | 97                                                 | 464    | 4.12                          | 5.39  | 38.27                        | 30.84 |
| Northeastern             | 3,911                    | 9,282   | 188                             | 194   | 158                                                | 1,033  | 10.13                         | 10.55 | 31.58                        | 15.34 |
| High-technology          | 13,849                   | 39,905  | 441                             | 1,254 | 1,020                                              | 5,458  | 31.08                         | 51.19 | 26.31                        | 15.03 |
| Eastern                  | 8,360                    | 24,237  | 225                             | 600   | 559                                                | 3,176  | 22.54                         | 47.29 | 22.85                        | 12.54 |
| Southern                 | 4,201                    | 13,462  | 167                             | 598   | 400                                                | 2,053  | 43.50                         | 60.30 | 30.45                        | 18.60 |
| Western                  | 503                      | 489     | 18                              | 21    | 21                                                 | 60     | 9.52                          | 6.67  | 39.56                        | 30.67 |
| Northeastern             | 785                      | 1,717   | 31                              | 35    | 40                                                 | 169    | 37.5                          | 29.59 | 32.61                        | 17.82 |

Source: *Support System for China Statistical Application*, All China Marketing Research, Beijing, China (<http://info.acmr.com>).

Table 2 Regression Estimates of the Industry Aggregates and Four Industrial Groups

|                     | All Industries<br>(1) | All Industries<br>(2) | Processing Industry<br>(3) | Light Manufacturing<br>(4) | Metal and Machinery<br>(5) | High-technology<br>(6) |
|---------------------|-----------------------|-----------------------|----------------------------|----------------------------|----------------------------|------------------------|
| ln K                | -0.143<br>(0.026)     | -0.138<br>(0.025)     | -0.588<br>(0.073)          | -0.222<br>(0.037)          | 0.032<br>(0.045)           | 0.148<br>(0.083)       |
| ln L                | 0.994<br>(0.030)      | 1.017<br>(0.029)      | 1.411<br>(0.073)           | 1.112<br>(0.047)           | 0.933<br>(0.054)           | 0.534<br>(0.090)       |
| ln H                | 0.631<br>(0.036)      | 0.707<br>(0.035)      | 0.696<br>(0.077)           | 0.427<br>(0.064)           | 0.729<br>(0.055)           | 0.999<br>(0.116)       |
| ln K $\times$ ln K  | 0.014<br>(0.003)      | 0.014<br>(0.003)      | 0.039<br>(0.007)           | 0.017<br>(0.004)           | 0.011<br>(0.005)           | -0.029<br>(0.010)      |
| ln L $\times$ ln L  | -0.022<br>(0.004)     | -0.021<br>(0.004)     | -0.026<br>(0.009)          | -0.014<br>(0.007)          | -0.011<br>(0.007)          | -0.059<br>(0.013)      |
| ln H $\times$ ln H  | -0.052<br>(0.006)     | -0.055<br>(0.006)     | -0.092<br>(0.013)          | -0.085<br>(0.011)          | -0.053<br>(0.009)          | -0.043<br>(0.016)      |
| ln K $\times$ ln L  | 0.006<br>(0.006)      | 0.004<br>(0.006)      | -0.017<br>(0.015)          | -0.007<br>(0.010)          | -0.004<br>(0.011)          | 0.101<br>(0.022)       |
| ln K $\times$ ln H  | 0.037<br>(0.007)      | 0.033<br>(0.007)      | 0.057<br>(0.015)           | 0.080<br>(0.012)           | 0.031<br>(0.012)           | 0.019<br>(0.020)       |
| ln L $\times$ ln H  | -0.043<br>(0.008)     | -0.043<br>(0.008)     | -0.070<br>(0.016)          | -0.074<br>(0.014)          | -0.040<br>(0.013)          | -0.056<br>(0.022)      |
| South               |                       | -0.155<br>(0.021)     | -0.129<br>(0.051)          | -0.109<br>(0.036)          | -0.201<br>(0.031)          | -0.171<br>(0.057)      |
| Northeast           | -0.169<br>(0.028)     | -0.236<br>(0.029)     | -0.165<br>(0.072)          | -0.192<br>(0.051)          | -0.292<br>(0.043)          | -0.203<br>(0.080)      |
| West                | -0.432<br>(0.022)     | -0.544<br>(0.023)     | -0.514<br>(0.055)          | -0.570<br>(0.041)          | -0.573<br>(0.033)          | -0.474<br>(0.069)      |
| Constant            | 6.473<br>(0.451)      | 7.171<br>(44.028)     | 6.711<br>(0.354)           | 7.724<br>(38.965)          | 5.107<br>(1.179)           | 5.942<br>(0.392)       |
| $\mu$               | 2.443<br>(0.443)      | 3.334<br>(44.027)     | 1.698<br>(0.204)           | 3.249<br>(38.964)          | 2.049<br>(1.166)           | 1.842<br>(0.177)       |
| $\eta$              | 0.002<br>(0.002)      |                       |                            |                            |                            | 0.034<br>(0.005)       |
| $\chi^2(nonlinear)$ | 369.20<br>(0.000)     | 382.26<br>(0.000)     | 203.19<br>(0.000)          | 263.01<br>(0.000)          | 70.69<br>(0.000)           | 59.59<br>(0.000)       |
| $\chi^2(regions)$   | 382.72<br>(0.000)     | 576.50<br>(0.000)     | 88.94<br>(0.000)           | 198.80<br>(0.000)          | 298.26<br>(0.000)          | 48.00<br>(0.000)       |
| $\chi^2(time)$      | 336.28<br>(0.000)     | 5612.82<br>(0.000)    | 948.67<br>(0.000)          | 1400.91<br>(0.000)         | 3088.17<br>(0.000)         | 15.18<br>(0.056)       |
| Nobs                | 28,915                | 28,915                | 6,233                      | 8,028                      | 11,692                     | 3,859                  |

*Note:* The figures in the parenthesis under the estimates are standard errors. The figures in the parenthesis under the chi-squares statistics are p-values. Nobs = number of observations. The data from Guizhou and Tibet are removed from the estimation for columns (1) and (2).

Table 3 Growth Decomposition for the Aggregates and Four Industrial Groups

|                     | Output Elasticity       |               |               |                  | Cost Share       |                   |           |         |
|---------------------|-------------------------|---------------|---------------|------------------|------------------|-------------------|-----------|---------|
|                     | $e_K$                   | $e_L$         | $e_H$         | $e$              | $s_K$            | $s_L$             | $s_H$     |         |
| Aggregates          | 0.335                   | 0.617         | 0.501         | 1.453            | 0.231            | 0.425             | 0.345     |         |
| Processing          | 0.372                   | 0.605         | 0.427         | 1.404            | 0.265            | 0.431             | 0.304     |         |
| Light Manufacturing | 0.322                   | 0.618         | 0.446         | 1.386            | 0.232            | 0.446             | 0.322     |         |
| Metal and Machinery | 0.337                   | 0.601         | 0.538         | 1.477            | 0.228            | 0.407             | 0.364     |         |
| High-technology     | 0.311                   | 0.658         | 0.558         | 1.527            | 0.204            | 0.431             | 0.366     |         |
|                     | Input Growth Effect (%) |               |               |                  | Scale Effect (%) |                   |           |         |
|                     | $s_K \dot{K}$           | $s_L \dot{L}$ | $s_H \dot{H}$ | $\dot{\Phi}$     | $e-1$            | $(e-1)\dot{\Phi}$ |           |         |
| Aggregates          | 2.00                    | 1.50          | 3.39          | 6.89             | 0.45             |                   | 3.08      |         |
| Processing          | 1.34                    | 0.85          | 2.98          | 5.17             | 0.39             |                   | 2.04      |         |
| Light Manufacturing | 2.35                    | 1.71          | 3.01          | 7.07             | 0.38             |                   | 2.71      |         |
| Metal and Machinery | 2.07                    | 1.38          | 3.67          | 7.12             | 0.47             |                   | 3.35      |         |
| High-technology     | 2.08                    | 2.56          | 3.73          | 8.37             | 0.52             |                   | 4.35      |         |
|                     | Estimated<br>$\dot{Y}$  | $\dot{\Phi}$  | Scale         | $\Delta\delta_t$ | $T\dot{E}$       | $T\dot{F}P$       | $\dot{Y}$ |         |
|                     | (1)                     | (2)           | (3)           | (4)              | (5)              | (3)+(4)+(5)       | (7)       | (7)-(1) |
| Aggregates          | 18.06                   | 6.89          | 3.08          | 8.10             | 0                | 11.18             | 18.19     | 0.13    |
| Processing          | 14.63                   | 5.17          | 2.04          | 7.43             | 0                | 9.46              | 14.51     | -0.13   |
| Light Manufacturing | 16.95                   | 7.07          | 2.71          | 7.17             | 0                | 9.88              | 17.54     | 0.60    |
| Metal and Machinery | 19.83                   | 7.12          | 3.35          | 9.36             | 0                | 12.71             | 19.92     | 0.10    |
| High-technology     | 20.56                   | 8.37          | 4.35          | 0.92             | 6.92             | 12.19             | 20.26     | -0.30   |

*Note:* Estimated  $\dot{Y}$  or estimated growth of output is the sum of input growth ( $\dot{\Phi}$ ) and  $T\dot{F}P$ .  $T\dot{F}P$  is the sum of adjusted scale effect (*Scale*), technology progress ( $\Delta\delta_t$ ) and change in technical efficiency ( $T\dot{E}$ ).  $\dot{Y}$  is the actual output growth and the last column shows the estimation errors.

Table 4 Growth Decomposition for Industries in Sub-Categories (%)

| Industry<br>(code) | Estimated $\dot{Y}$ | $\dot{\Phi}$ | Scale | $\Delta\delta_i$ | $T\dot{E}$ | $T\dot{F}P$ | $\dot{Y}$ |         |
|--------------------|---------------------|--------------|-------|------------------|------------|-------------|-----------|---------|
|                    | (1)                 | (2)          | (3)   | (4)              | (5)        | (3)+(4)+(5) | (7)       | (7)-(1) |
| 13                 | 15.87               | 5.97         | 2.30  | 7.61             | 0          | 9.90        | 15.83     | -0.04   |
| 14                 | 18.44               | 6.83         | 3.33  | 8.27             | 0          | 11.61       | 17.55     | -0.89   |
| 15                 | 16.52               | 7.12         | 1.87  | 1.88             | 5.66       | 9.40        | 16.57     | 0.05    |
| 16*                | 3.83                | 3.72         | 3.76  | -3.65            | 0          | 0.11        | 5.48      | 1.66    |
| 17                 | 11.60               | 1.65         | 0.68  | 9.28             | 0          | 9.96        | 11.09     | -0.51   |
| 18                 | 11.27               | 5.29         | 2.22  | 3.76             | 0          | 5.98        | 11.53     | 0.26    |
| 19                 | 15.06               | 4.74         | 0.58  | 9.74             | 0          | 10.32       | 15.01     | -0.05   |
| 20                 | 19.58               | 8.33         | 2.94  | 8.31             | 0          | 11.25       | 19.97     | 0.39    |
| 21                 | 18.59               | 10.51        | 5.06  | 3.02             | 0          | 8.08        | 19.03     | 0.43    |
| 22                 | 12.15               | 3.64         | 1.82  | 6.69             | 0          | 8.51        | 12.66     | 0.51    |
| 23                 | 8.95                | 4.06         | 2.24  | 2.65             | 0          | 4.89        | 10.58     | 1.63    |
| 24                 | 20.50               | 11.94        | 4.78  | 3.78             | 0          | 8.56        | 21.30     | 0.80    |
| 25*                | 27.69               | 9.42         | 2.13  | 16.13            | 0          | 18.26       | 28.13     | 0.44    |
| 26                 | 18.23               | 6.73         | 1.43  | 10.06            | 0          | 11.50       | 19.01     | 0.78    |
| 27                 | 15.62               | 7.25         | 3.47  | 4.90             | 0          | 8.37        | 15.75     | 0.13    |
| 28                 | 14.83               | 5.04         | 2.44  | 7.34             | 0          | 9.79        | 13.57     | -1.25   |
| 29                 | 14.33               | 4.89         | 1.66  | 7.77             | 0          | 9.43        | 14.88     | 0.55    |
| 30                 | 16.30               | 6.68         | 2.02  | 7.60             | 0          | 9.62        | 16.99     | 0.68    |
| 31                 | 16.58               | 4.93         | 2.29  | 9.36             | 0          | 11.65       | 16.67     | 0.09    |
| 32                 | 22.31               | 5.87         | 2.21  | 14.23            | 0          | 16.44       | 22.18     | -0.13   |
| 33*                | 30.95               | 11.22        | 4.39  | 15.34            | 0          | 19.73       | 31.57     | 0.63    |
| 34                 | 19.41               | 8.25         | 2.62  | 6.68             | 1.86       | 11.16       | 18.91     | -0.51   |
| 35                 | 20.03               | 5.95         | 3.95  | 10.14            | 0          | 14.08       | 20.32     | 0.29    |
| 36                 | 19.62               | 6.10         | 4.60  | 8.92             | 0          | 13.52       | 19.48     | -0.14   |
| 37                 | 22.47               | 9.58         | 4.88  | 8.01             | 0          | 12.89       | 22.26     | -0.21   |
| 40                 | 21.57               | 8.07         | 4.13  | 5.27             | 4.10       | 13.50       | 21.34     | -0.23   |
| 41                 | 18.11               | 8.34         | 4.70  | 0.31             | 4.76       | 9.77        | 16.35     | -1.76   |
| 42                 | 20.76               | 8.37         | 4.52  | 2.57             | 5.30       | 12.39       | 22.02     | 1.25    |
| 43                 | 24.12               | 9.79         | 2.13  | 12.19            | 0          | 14.32       | 24.56     | 0.44    |
| Average*           | 17.42               | 6.77         | 2.88  | 7.77             | —          | 10.65       | 17.52     | 0.10    |
| Std                | 3.78                | 2.29         | 1.33  | 2.71             | —          | 2.60        | 3.76      | 0.72    |
| Minimum            | 8.95                | 1.65         | 0.58  | 2.65             | —          | 4.89        | 10.58     | -1.76   |
| Maximum            | 24.12               | 11.94        | 5.06  | 14.23            | —          | 16.44       | 24.56     | 1.63    |

Note: \* Industrial codes 16, 25, and 33 are removed from the descriptive statistics calculation shown in the last four rows.

Table 5 Growth Decomposition for Four Industrial Groups in Four Regions (%)

| Processing Industry          |                     |              |       |                  |            |             |           |         |
|------------------------------|---------------------|--------------|-------|------------------|------------|-------------|-----------|---------|
| Region                       | Estimated $\dot{Y}$ | $\dot{\Phi}$ | Scale | $\Delta\delta_i$ | $T\dot{E}$ | $T\dot{F}P$ | $\dot{Y}$ |         |
|                              | (1)                 | (2)          | (3)   | (4)              | (5)        | (3)+(4)+(5) | (7)       | (7)-(1) |
| Eastern                      | 11.88               | 4.45         | 1.70  | 5.72             | 0          | 7.42        | 12.08     | 0.21    |
| Southern                     | 17.11               | 7.32         | 4.00  | 5.80             | 0          | 9.80        | 17.37     | 0.26    |
| Western                      | 15.92               | 4.04         | 1.73  | 10.15            | 0          | 11.88       | 14.65     | -1.26   |
| Northeastern                 | 16.54               | 4.73         | 1.00  | 10.82            | 0          | 11.81       | 16.70     | 0.16    |
| All                          | 14.63               | 5.17         | 2.04  | 7.43             | 0          | 9.46        | 14.51     | -0.13   |
| Light Manufacturing Industry |                     |              |       |                  |            |             |           |         |
| Region                       | Estimated $\dot{Y}$ | $\dot{\Phi}$ | Scale | $\Delta\delta_i$ | $T\dot{E}$ | $T\dot{F}P$ | $\dot{Y}$ |         |
|                              | (1)                 | (2)          | (3)   | (4)              | (5)        | (3)+(4)+(5) | (7)       | (7)-(1) |
| Eastern                      | 14.99               | 5.95         | 2.36  | 6.69             | 0          | 9.04        | 15.50     | 0.51    |
| Southern                     | 19.75               | 9.41         | 4.07  | 2.54             | 3.74       | 10.35       | 20.57     | 0.82    |
| Western                      | 15.33               | 4.85         | 2.24  | 8.24             | 0          | 10.48       | 16.10     | 0.77    |
| Northeastern                 | 19.87               | 7.92         | 2.86  | 9.09             | 0          | 11.95       | 20.84     | 0.97    |
| All                          | 16.95               | 7.07         | 2.71  | 7.17             | 0          | 9.88        | 17.54     | 0.60    |
| Metal and Machinery Industry |                     |              |       |                  |            |             |           |         |
| Region                       | Estimated $\dot{Y}$ | $\dot{\Phi}$ | Scale | $\Delta\delta_i$ | $T\dot{E}$ | $T\dot{F}P$ | $\dot{Y}$ |         |
|                              | (1)                 | (2)          | (3)   | (4)              | (5)        | (3)+(4)+(5) | (7)       | (7)-(1) |
| Eastern                      | 18.85               | 7.17         | 2.97  | 8.71             | 0          | 11.68       | 18.87     | 0.03    |
| Southern                     | 22.90               | 9.15         | 4.18  | 9.57             | 0          | 13.75       | 23.48     | 0.58    |
| Western                      | 16.66               | 4.51         | 2.30  | 9.85             | 0          | 12.15       | 16.82     | 0.16    |
| Northeastern                 | 21.30               | 6.52         | 3.70  | 8.31             | 2.77       | 14.78       | 20.42     | -0.88   |
| All                          | 19.83               | 7.12         | 3.35  | 9.36             | 0          | 12.71       | 19.92     | 0.10    |
| High-technology Industry     |                     |              |       |                  |            |             |           |         |
| Region                       | Estimated $\dot{Y}$ | $\dot{\Phi}$ | Scale | $\Delta\delta_i$ | $T\dot{E}$ | $T\dot{F}P$ | $\dot{Y}$ |         |
|                              | (1)                 | (2)          | (3)   | (4)              | (5)        | (3)+(4)+(5) | (7)       | (7)-(1) |
| Eastern                      | 21.22               | 8.57         | 4.77  | 1.76             | 6.12       | 12.65       | 20.31     | -0.91   |
| Southern                     | 20.98               | 9.45         | 5.62  | 5.93             | 0.00       | 11.55       | 21.35     | 0.37    |
| Western                      | 21.40               | 7.52         | 6.11  | 1.69             | 6.09       | 13.88       | 20.80     | -0.60   |
| Northeastern                 | 16.61               | 5.03         | 2.52  | 9.06             | 0          | 11.58       | 16.49     | -0.12   |
| All                          | 20.56               | 8.37         | 4.35  | 0.92             | 6.92       | 12.19       | 20.26     | -0.30   |

Note: The data of Guizhou and Tibet are removed from the estimation for the Western region.

Table 6 Growth Decomposition for Provinces (%)

|              | Estimated $\dot{Y}$ | $\dot{\Phi}$ | Scale | $\Delta\delta_t$ | $T\dot{E}$ | $T\dot{F}P$ | $\dot{Y}$ |         |
|--------------|---------------------|--------------|-------|------------------|------------|-------------|-----------|---------|
|              | (1)                 | (2)          | (3)   | (4)              | (5)        | (3)+(4)+(5) | (7)       | (7)-(1) |
| Nation       | 18.06               | 6.89         | 3.08  | 8.10             | 0          | 11.18       | 18.19     | 0.13    |
| Eastern      | 16.74               | 6.52         | 2.82  | 7.41             | 0          | 10.23       | 16.81     | 0.07    |
| Beijing      | 8.64                | 2.09         | 1.53  | 5.03             | 0          | 6.55        | 8.37      | -0.27   |
| Tianjin      | 11.50               | 3.83         | 2.76  | 4.91             | 0          | 7.67        | 11.73     | 0.23    |
| Hebei        | 17.67               | 5.80         | 1.88  | 8.74             | 1.25       | 11.87       | 17.42     | -0.25   |
| Shanxi       | 14.72               | 5.11         | 2.32  | 7.29             | 0          | 9.61        | 14.91     | 0.19    |
| Shanghai     | 12.85               | 4.73         | 2.17  | 5.94             | 0          | 8.11        | 12.91     | 0.07    |
| Jiangsu      | 16.39               | 8.04         | 1.09  | 7.26             | 0          | 8.35        | 16.36     | -0.04   |
| Zhejiang     | 21.13               | 10.56        | 5.60  | 4.97             | 0          | 10.57       | 21.21     | 0.08    |
| Anhui        | 22.28               | 9.41         | 4.08  | 8.78             | 0          | 12.86       | 22.42     | 0.14    |
| Shandong     | 22.55               | 10.61        | 3.05  | 8.90             | 0          | 11.94       | 23.11     | 0.56    |
| Henan        | 19.93               | 5.78         | 1.50  | 12.65            | 0          | 14.15       | 19.90     | -0.03   |
| Hubei        | 14.68               | 5.48         | 2.13  | 1.87             | 5.20       | 9.20        | 14.83     | 0.15    |
| Southern     | 20.58               | 8.82         | 4.41  | 3.20             | 4.15       | 11.76       | 21.13     | 0.54    |
| Fujian       | 21.58               | 11.31        | 5.85  | 4.42             | 0          | 10.27       | 21.64     | 0.06    |
| Jiangxi      | 22.90               | 8.48         | 3.50  | 9.39             | 1.53       | 14.41       | 24.21     | 1.32    |
| Hunan        | 23.53               | 9.90         | 4.78  | 2.60             | 6.25       | 13.63       | 24.25     | 0.72    |
| Guangdong    | 15.24               | 8.65         | 2.07  | 4.51             | 0          | 6.59        | 15.28     | 0.04    |
| Guangxi      | 17.58               | 6.09         | 3.24  | 8.25             | 0          | 11.49       | 19.36     | 1.78    |
| Hainan       | 8.13                | 3.51         | 2.09  | 2.53             | 0          | 4.62        | 12.91     | 4.78    |
| Chongqing    | 21.11               | 7.92         | 5.09  | 8.10             | 0          | 13.19       | 20.85     | -0.26   |
| Sichuan      | 25.10               | 10.09        | 4.94  | 10.08            | 0          | 15.02       | 25.78     | 0.68    |
| Western      | 16.53               | 4.88         | 2.43  | 9.22             | 0          | 11.65       | 16.60     | 0.08    |
| Mongolia     | 27.22               | 11.34        | 6.08  | 9.80             | 0          | 15.88       | 28.42     | 1.20    |
| Guizhou      | 16.10               | 3.91         | 2.86  | 9.34             | 0          | 12.20       | 14.75     | -1.35   |
| Yunnan       | 15.18               | 3.70         | 2.04  | 9.44             | 0          | 11.48       | 15.19     | 0.01    |
| Tibet        | 8.08                | -1.21        | -0.69 | 9.98             | 0          | 9.29        | 6.25      | -1.83   |
| Shaanxi      | 12.75               | 4.65         | 3.05  | 5.05             | 0          | 8.10        | 14.60     | 1.85    |
| Gansu        | 14.08               | 3.33         | 1.17  | 7.47             | 2.11       | 10.75       | 14.98     | 0.89    |
| Qinghai      | 16.26               | 4.07         | 1.42  | 10.78            | 0          | 12.20       | 13.17     | -3.10   |
| Ningxia      | 19.22               | 6.85         | 3.37  | 9.00             | 0          | 12.37       | 18.96     | -0.26   |
| Xinjiang     | 14.74               | 4.32         | 1.39  | 9.04             | 0          | 10.43       | 14.03     | -0.71   |
| Northeastern | 19.28               | 6.38         | 2.78  | 10.11            | 0          | 12.89       | 19.28     | 0.01    |
| Liaoning     | 22.57               | 8.28         | 2.66  | 9.82             | 1.81       | 14.29       | 22.78     | 0.21    |
| Jilin        | 19.87               | 5.51         | 1.89  | 7.49             | 4.97       | 14.36       | 19.48     | -0.39   |
| Heilongjiang | 14.22               | 5.22         | 2.94  | 6.07             | 0          | 9.00        | 14.11     | -0.12   |

Figure 1  
Economic Growth with Technical Progress and Technical Efficiency Change

Figure 1A Technical Progress without Technical Efficiency Change

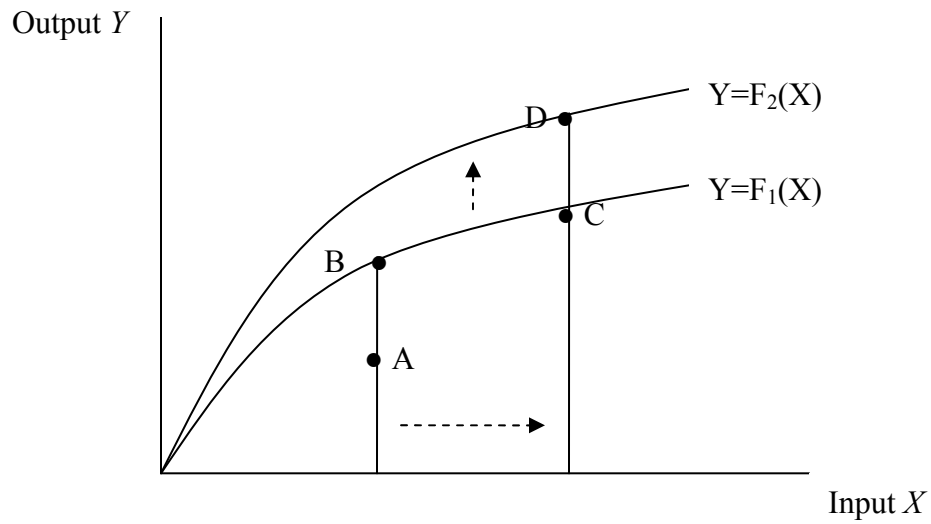


Figure1B Technical Efficiency Change without Technical Progress

