經濟學碩士 學位論文

Productivity Growth, Technical Progress and Economies of Scale Of the Chinese Economy:

Sources of China's Economic Growth Between 1978-2003

指導教授: 羅　昊　洙

2005 年 **12** 月

한국해양대학교 대학원

국제무역경제학부

李　　　　宇

本 論文을 李宇의 經濟學碩士 學位論文으로 認准함.

委員長　兪 日 善　㊞

委　員　金 鐘 碩　㊞

委　員　羅 昊 洙　㊞

2 0 0 5 年　12 月

韓 國 海 洋 大 學 校　大 學 院

貿 易 學 科

Productivity Growth, Technical Progress and Economies of Scale Of the Chinese Economy:

Sources of China[1]'s Economic Growth Between 1978-2003

Key words: Chinese Economy, Translog Cost Function, Efficiency TFP, Technical Change

[1] In this paper, China refers to People's Republic of China, not including Taiwan (China Taipei) Hong Kong and Macao. When necessary, we also use Mainland China instead of "China" to clarify the facts.

Abstract

This study mainly focuses on estimating the cost structure of the Chinese economy over the period of 1978-2003. The economic characteristics of China are analyzed by applying translog cost function estimation. Four input factors including capital, labor, imports and intermediate goods are specified in the cost function. In addition, technology variable is also employed to investigate the effects of the technical change.

Firstly, this study has confirmed the cost structure of the China's economy is labor-intensive, material-intensive and capital-saving natures

Secondly, the yearly technical change progress is presented, in the year 1978 to 2003 the average technical change rate is 5.8%. Technical change plays an important part in the growth of Chinese economy.

Thirdly, the numerical value of ES is found to be 0.964 indicating that small economies of scale exist in the China's overall economy.

Fourthly, we combine the technical change rates with efficiency change rate, the total factor productivity growth rate can be calculated, and the average rate is 14.7%.

In conclusion, even through Chinese economy is still the labor intensive economy, it is experiencing a rapid technical change and growth of economies of scale, the total factor productivity grows rapidly.

國 文 抄 錄

題目: 中國經濟의 生産性 增加, 技術進步 그리고 規模의 經濟: 1978-2003 사이의 中國의 經濟成長의 源泉

本 硏究는 1978 년부터 2003 년까지의 中國經濟의 費用函數를 推定하는데 초점을 맞추고 있다. 中國의 經濟的 特徵은 超越代數函數의 推定을 適用함으로써 分析된다. 資本, 勞動, 輸入, 中間財 등을 包含하는 네 가지의 投入要素들이 費用函數에서 設定되어 模型이 構成되었다. 追加하여 技術變數 또한 技術變化의 效果를 調査하기 위하여 使用되었다.
發見된 事實은 다음과 같다.

첫째, 中國經濟全體의 費用構造를 檢討한 結果 中國經濟에서 勞動集約的中國經濟의構造를 갖는 費用構造를 發見하였고, 資本의 分配몫(share)은 比較的 낮은 生産構造를 갖고 있음을 確認하였다.

둘째, 연평균 技術進步率이 提示되었는데 1978 년부터 2003 년까지 平均技術變化率은 5.5%로 나타났다. 技術變化가 中國經濟成長에서 重要한 役割을 하고 있다.

셋째, 規模의 經濟의 測定値는 0.964 로 나타났고 이는 中國經濟가 지난 20 여년간에 걸쳐 若干의 規模의 經濟를 示顯하였다는 것을 보여주는 것이다.

넷째, 技術變化率과 效率性變化率을 結合하여 聽要素生産性變化率을 測定하였는데 年平均 14.7%의 總要素生産性의 增加率을 보여주었다.

結論的으로 中國經濟가 아직도 勞動集約的 經濟이기는 하지만 中國經濟는 比較的 빠른 技術變化率, 若干의 規模의 經濟, 상당한 總要素生産性의 增加율 등을 經驗하였다고 할 수 있다.

Contents:

Contents of Tables:

1. Introduction

1.1 The purpose of the study

In the last twenty years, China has maintained a high economic growth rate that has attracted worldwide attention. The whole economy gradually transfers from a centrally planned to a market one. Economic performance improved significantly between 1978 and 2003, as the effect of progressively opening and reform policy measures. China's annual economic growth rate averaged 9 percent in this more than 20-years reform period, a remarkable record indeed, particularly in comparison with the low performance of the other transition economies.

Aggregate productivity refers to output per unit input. It reflects technical change as well as technical efficiency change. In the study of economic growth, accounting for productivity growth is very important as the economy's long run growth in inputs. Young (1995) believes that growth in East Asia, including China is driven by a scale effect, and that technical innovations are not adopted faster than in other counties.

In Young's 1995 paper, he used a translog production function to represent the economy's aggregate technology, and estimated the "Solow residuals" to obtain TFP indexes for four different countries of the "Asia Tigers[2]". In his model, technical efficiency in production is assumed, i.e., the economy is assumed to be producing on the frontier. He investigated the cases of Hong Kong, Singapore, Taiwan, and South Korea. Following Young's study, this paper is provided, to study the Chinese productivity growth, technical progress and economies of scales of recent two decades.

This study mainly focuses on estimating the cost structure of the Chinese economy over the period of 1978-2003 on the purpose of finding how the Chinese economy carried out in the recent years after the Chinese economic reform. The economic characteristics of China are analyzed by applying translog cost function estimation. Four input factors including capital, labor, imports and intermediate goods are specified in the cost function. In addition technology variable are also employed to investigate the effects the technical change, the economic scale and the total factor production (TFP).

The paper is organized as follows: The section 2 gives the theoretical model of cost function. In section 2.1 the particular translog cost function is chosen and discussed. And section 2.2 specifies the cost function employed

[2] The economies of for tigers: Hong Kong, Singapore, south Korea and Taiwan

in this study while section 2.3 shows the system equation after proper transformation. In the section 3 of this essay, both original and conversion of the data are presented, and in the last part of this section the date is estimated by the model presented in section 2. Finally, some concluding remarks are drawn in section 4.

1.2 Previous studies

In the last two decades in China, despite spectacular economic performance, there are relatively few studies on China's overall productivity performance. Ezaki and Sun (1990) studied TFP growth for china. They reported that the growth rate of TFP has been fairly high, at about 3% to 4% from 1981 to 1995[3]. They used a growth accounting approach directly from the data; no econometric estimation was drawn. In his recent paper about China, Young (1999) estimated non-agricultural TFP growth rate to be 1.4% per year during the period of 1978 to 1998. Similar to his claim for the four "Asian Tigers", he stated "the productivity performance of the non-agricultural economy (of China) during the reform period was respectable, but not outstanding[4]." Kalirajan et al (1996) studied agricultural total factor productivity (TFP) growth of the Chinese province and reported that TFP

[3] Total factor productivity Growth in Japan, South Korea, and Taiwan Nirikar Singh and Hung Trieu (1996)
[4] A working paper version of out results was used by Husain (1995), in his response to Krugman. The same issue of Foreign Affairs contains other comments as well.

growth in the period of 1970-1978 was negative in twenty out of twenty-eight provinces. In the 1979-1983 reform periods, agricultural TFP growth was positive in almost all provinces, but it reverted to negative in sixteen out of twenty-eight provinces in the post-reform period of 1984-1987. Woo (1996) reported China's net TFP growth rate to be 1.1 to 1.3 percent from 1978 to 1993, and 0.3 to 0.6 percent from 1985 to 1993. Wu (1999) used a stochastic frontier approach to estimate TFP growth, including both the technical change rate and the efficiency change rate for Chinese provinces from 1978 to 1995. The TFP growth rate in this study has been increasing from a negative territory to a positive one, although still a small figure, during the reform period.

Traditionally, total factor productivity, the ratio of an index of aggregate output to an index of aggregate input, has been used to measure productivity[5]. Changes in TFP can be decomposed into components measuring changes in technical efficiency, in economic of scale and in technology.

2. The theoretical model[6]

[5] See Baumol, Panzar, and Willig(1982) for a general discussion of mulitproduct cost functions. Clark (1988) and Humphrey (1990) discuss recent studies of costs at depository institutions.

[6] Traditional cost studies could possibility confound scale economies and differences in X-efficiency at different output levels. This potential problem does not appear to be of practical significance, however. Several rsearchers have estimated scale economies using both traditional cost functions and frontier estimation methods and found little or no differences in results from the two approaches(berrger and Humphrey 1991; McAlister and McManus 1993; Master 1993) for further discussion, see Berger et al.(1993)

2.1 The model formulation

Let “c” represents the observed cost of production, “C” represents the functional form of translog, “y” represents the output quantity, “w” represents the vector of input prices “β” represents the vector of unknown parameters to be estimated and “μ” represents a non-negative cost inefficiency effect (which often assumed to have a half-normal or truncated-normal distribution). The stochastic cost frontier[7] will be

$$Lnc=C(y, w, \beta)+v+\mu \qquad \ldots\ldots(1)$$

Because the cost function represents minimum cost, whereas the production function represents maximum outputs the inefficiency effect μ is added in the cost frontier, instead of being subtracted, as in the case of the production frontier.

The parameters of the cost frontier of equation (1) can be estimated using standard econometric methods since the y and w are assumed to be exogenously determined. Schmidt and Lovell (1997) specified a Cobb-Douglas technology for steam-powered electricity-generating plants

[7] This comes from the Introduction to Applied Econometrics (Kenneth G. Stewart)

and showed that the stochastic cost frontier can be estimated in a similar manner to the stochastic production frontiers using either ML or COLS estimators. The overall cost efficiencies can be decomposed into their technical and allocative components if the cost function implied by estimated cost function can be explicitly derived[8].

A maximum-likehood systems estimator, involving the cost function and the factor-demand equations, provides more efficient estimators of the parameters of a cost function than the single equation estimator. The systems approach also has the advantage of explicitly accounting for allocative inefficiency which is reflected in the error terms on the factor demand equations, which represent violations of the first-order conditions for cost minimization.

For a simple example of the systems approach, consider a translog cost function involving one output and two inputs:

$$\ln c = \beta_0 + \beta_1 \ln w_1 + \beta_2 \ln w_2 + \beta_3 \ln y + \beta_{12} \ln w_1 \ln w_2 + \beta_{13} \ln w_1 \ln y + \beta_{23} \ln w_2 \ln y$$
$$+ (1/2)[\beta_{11} (\ln w_1)^2 + \beta_{22} (\ln w_2)^2 + \beta_{33} (\ln y)^2]$$

The input-demand equations (derived using Shephard's Lemma) are the

[8] The translog cost function is flexible at the point of approximation, but it imposes generally a specific structure, namely, a symmetric U-shaped average cost curve. If this assumption does not hold generally, then the cost function would be misspecified, and estimates of scale economies derived from it would be biased.

share equations in the case of the translog. For the two-input example they are:

$$(w_1\ x_1/\mathrm{c}) = \beta_1 + \beta_{12}\ln w_2 + \beta_{13}\,\mathrm{lny} + \beta_{11}\ln w_1 \qquad \ldots\ldots(2)$$

$$(w_2\ x_2/\mathrm{c}) = \beta_2 + \beta_{12}\ln w_1\ \beta_{23}\,\mathrm{lny} + \beta_{22}\ln w_2 \qquad \ldots\ldots(3)$$

Where, the dependent variables are the shares of total cost for that input.

2.2 The four-input translog cost function

The translog function is an attractive flexible function which has both linear and quadratic terms with the ability of using more than two factor inputs. A maximum-likehood systems estimator, involving the cost function and the factor-demand equations, provides more efficient estimators of the parameters of a cost function than the single-equation estimator. The systems approach also has the advantage of explicitly accounting for allocative inefficiency, which is reflected in the error terms on the factor demand equations, which represent violations of the first-order conditions for cost minimization. The four-input translog production function can be written in terms of logarithms as follows,

$$\mathrm{Lnc} = \beta_0 + \beta_k \ln w_K + \beta_l \ln w_L + \beta_m \ln w_M + \beta_{im}\ln w_{IM} + \beta_y\,\mathrm{lny} + \beta_t\,\mathrm{t} + \beta_{kl}\ln w_K \ln w_L$$

$$+\beta_{km}\ln w_K \ln w_M + \beta_{kim}\ln w_K \ln w_{IM} + \beta_{ky}\ln w_K \ln y + \beta_{kt}\ln w_K t + \beta_{lm}\ln w_L \ln w_M$$

$$+\beta_{\lim}\ln w_L \ln w_{IM} + \beta_{ly}\ln w_L \ln y + \beta_{lt} t\ln w_L + \beta_{mim}\ln w_M \ln w_{IM} + \beta_{my}\ln w_M \ln y$$

$$+\beta_{mt} t\ln w_M + \beta_{imy}\ln w_{IM}\ln y + \beta_{imt} t\ln w_{IM} + \beta_{yt} t\ln y + 1/2\,\beta_{kk}\ln w_K{}^2$$

$$+1/2\,\beta_{ll}\ln w_L{}^2 + 1/2\,\beta_{mm}\ln w_M{}^2 + 1/2\,\beta_{imim}\ln w_{IM}{}^2 + 1/2\,\beta_{yy}\ln y^2 + 1/2\,\beta_{tt} t^2 \quad \ldots\ldots(4)$$

Where, “c” is the index of real total gross output which is the total cost factor of the Chinese economy. The input factors of this model used are “w_K”, “w_L”, “w_M”, and “w_{IM}” where “w_K” is the index of price of real stock of capital input (interest rate), “w_L” is the index of real price of labor input (wage), “w_M” is the index of real price of intermediate material input, and “w_{IM}” is the index of whole sale price of import. β_0 is the intercept or the constant term. β_k, β_l, β_m and β_{im} are first derivatives. β_{kk}, β_{ll}, β_{mm} and β_{imim} are their own second derivatives. β_{kl}, β_{km}, β_{kim} and so on are their cross second derivatives.

Under the perfect competition assumption, output elasticity with respect to input equals cost share of that input. Thus, we can get a system of equations from differentiating the translog cost function with respect to each factor input, we derive the output elasticity or the factor-share equtions[9]:

[9] The assumption, on which the equation after differencing cost function which respect to factors is the share of the factors, is that firms act as producers in a competitive market, thus form the first order condition, we can derive the postulates.

$$sk=\beta_k+\beta_{kl}\ln w_L+\beta_{km}\ln w_M+\beta_{kim}\ln w_{IM}+\beta_{ky}\,\text{lny}+\beta_{kt}\,\text{t}+1/2\,\beta_{kk}\ln w_K$$

$$sl=\beta_l+\beta_{kl}\ln w_K+\beta_{lm}\ln w_M+\beta_{\mathrm{lim}}\ln w_{IM}+\beta_{ly}\,\text{lny}+\ \beta_{lt}\,\text{t}+1/2\,\beta_{ll}\ln w_L$$

$$sim=\beta_{im}+\beta_{kim}\ln w_K+\beta_{\mathrm{lim}}\ln w_L+\beta_{mim}\ln w_M+\beta_{imy}\,\text{lny}+\beta_{imt}\,\text{t}+1/2\,\beta_{imim}\ln w_{IM}$$

Where "sk" , "sl", "sim" means the share of capital, the share of labor and the share of import. β_k represents the average cost share of capital, β_{kk} , β_{km}, and β_{kim} represent constant capital share elasticity with respect to capital, capital share elasticity with respect to labor, and capital share elasticity with respect to intermediate material input respectively and so on. β_{kl} , β_{lm} and β_{ll} are constant material share elasticity of labor with respect to capital, with respect to intermediate materials and with respect to labor. β_{km} , β_{lm}, and β_{mim} are constant material share elasticity of the intermediate material with respect to capital, to labor and with respect to the import materials. Similarly, β_{kim} , β_{lim} , and β_{mim} are the constant material share elasticity of the import goods with respect to the capital factor, with respect to the labor and with respect to the intermediate materials.

From homogeneity of cost function in the vector factor prices, we impose the following restrictions[10]:

[10] By assumption the cost function is linearly homogeneous in input prices and linearly homogeneous in output. Cost Minimization, Technical Progress and the Aggregate Demand for Imports Korea,1963-81 nah, hosoo (Feb. 1984)

$$\beta_m = 1 - \beta_k - \beta_l - \beta_{im}$$

$$\beta_{kim} = -\beta_{kl} - \beta_{km} - \beta_{ky}$$

$$\beta_{\mathrm{lim}} = -\beta_{kl} - \beta_{lm} - \beta_{ly}$$

$$\beta_{mim} = -\beta_{kim} - \beta_{\mathrm{lim}} - \beta_{imy} \quad [= \beta_{kl} + \beta_{km} + \beta_{ky} + \quad \beta_{kl} + \beta_{lm} + \beta_{ly} - \beta_{imy}]$$

$$\beta_{my} = -\beta_{ky} - \beta_{ly} - \beta_{imy}$$

$$\beta_{mt} = -\beta_{kt} - \beta_{lt} - \beta_{imt}$$

2.3 Formation of the system equations

Estimating the cost share equations jointly with the translog cost function in the equation above improves the efficiency of the estimation process. Further the number of degrees of freedom is increased, without an increase in the number of parameters to be estimated. Since the cost shares sum “c” unity, there are four linearity independent factor share equations. Thus, in forming of the estimated system, one of the share equations is omitted. The parameters estimated are invariant with respect to the omitted equation, since a maximum likelihood estimator is used. By the restriction above, we can transform the system equations to:

$$\text{lnc} = \beta_0 + \beta_k \ln w_K + \beta_l \ln w_L + \ln w_M - \beta_k \ln w_M - \beta_l \ln w_M - \beta_{im} \ln w_M + \beta_{im} \ln w_{IM}$$

$+\beta_y$ lny+ β_t t+ $\beta_{kl}\ln w_K \ln w_L + \beta_{km}\ln w_K \ln w_M$ - $\beta_{kl}\ln w_K \ln w_{IM}$ - $\beta_{km}\ln w_K \ln w_{IM}$

- $\beta_{ky}\ln w_K \ln w_{IM}$ $+\beta_{ky}\ln w_K$ lny+ β_{kt} tln $w_K + \beta_{lm}\ln w_L \ln w_M$ - $\beta_{kl}\ln w_L \ln w_{IM}$

- $\beta_{lm}\ln w_L \ln w_{IM}$ - $\beta_{ly}\ln w_L \ln w_{IM}$ $+\beta_{ly}\ln w_L$ lny+ β_{lt} tln w_L +2 $\beta_{kl}\ln w_M \ln w_{IM}$

$+\beta_{km}\ln w_M \ln w_{IM} + \beta_{ky}\ln w_M \ln w_{IM} + \beta_{lm}\ln w_M \ln w_{IM} + \beta_{ly}\ln w_M \ln w_{IM}$

- $\beta_{imy}\ln w_M \ln w_{IM}$ $+\beta_{my}\ln w_M$ lny+ $\beta_{mt}\ln w_M$ t+ $\beta_{imy}\ln w_{IM}$ lny+ β_{imt} tln w_{IM}

$+\beta_{yt} t\ln y + \beta_{kk}\ln w_K{}^2$ +1/2 $\beta_{ll}\ln w_L{}^2$ +1/2 $\beta_{mm}\ln w_M{}^2$ +1/2 $\beta_{imim}\ln w_{IM}{}^2$

+1/2 β_{yy} lny ^{2} +1/2 β_{tt} t ^{2}

sk= $\beta_k + \beta_{kl}\ln w_L + \beta_{km}\ln w_M$ - $\beta_{kl}\ln w_{IM}$ - $\beta_{km}\ln w_{IM}$ - $\beta_{ky}\ln w_{IM}$ $+\beta_{ky}$ lny+ β_{kt} t

$+\beta_{kk}\ln w_K$

sl= $\beta_l + \beta_{kl}\ln w_K + \beta_{lm}\ln w_M$ - $\beta_{kl}\ln w_{IM}$ - $\beta_{lm}\ln w_{IM}$ - $\beta_{ly}\ln w_{IM}$ $+\beta_{ly}$ lny+ β_{lt} t

$+\beta_{ll}\ln w_L$

sim= $\beta_{im} + \beta_{kim}\ln w_K + \beta_{\lim}\ln w_L$ +2 $\beta_{kl}\ln w_M + \beta_{km}\ln w_M + \beta_{ky}\ln w_M + \beta_{lm}\ln w_M$

$+\beta_{ly}\ln w_M$ - $\beta_{imy}\ln w_M + \beta_{imy}$ lny+ β_{imt} t+ $\beta_{imim}\ln w_{IM}$

For the translog cost function the own-price elasiticities of demand are:

$$\varepsilon_{ii} = \frac{\beta_{ii} + S_i(S_i - 1)}{S_i}$$

and the cross-price elasticities are

$$\varepsilon_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i} \qquad (i \neq j)$$

Following Caves et al (1984) and Filippini (1996) we define economies of scale (ES) as the rate increase in total cost brought about by a proportional increase in output, holding all input prices fixed. This is equivalent to the inverse of the elasticities of variable cost with respect to output,

$$ES = \frac{\partial \ln c}{\partial \ln y} = \beta_y + \beta_{ky} \ln w_K + \beta_{ly} \ln w_L + \beta_{my} \ln w_M + \beta_{imy} \ln w_{IM} + \beta_{yy} \ln w_Y + \beta_{yt} t$$

And the technical change progress (TP) can be calculated by the equation:

$$\text{TP}=-\frac{\partial \ln c}{\partial t} = \beta_t + \beta_{kt} \ln w_K + \beta_{lt} \ln w_l + \beta_{mt} \ln w_m + \beta_{imt} \ln w_{im} + \frac{1}{2}\beta_{tt} t$$

As reference to the total factor productivity (TFP), the total factor productivity consists of two parts: the economies of scale and the technical change, so the TFP can be calculated by the following equation:

$$\text{TFP}= ES \frac{d \ln y}{dt} + TP$$

3 Empirical results

3.1 The data

3.1.1 Sources[11] of the data

The following data of year 1978-2003 were taken from the Chinese statistical year book, various issues. Including real total gross output (RTGO), which is the total cost factor (TC); the real GDP (RGDP) which is the total output factor (Y), real capital stock (RK) which is the capital factor input (K), the labor (L) which is the labor factor number, real intermediate material (RM) which is the total intermediate factor input (M), real import value (RIM) which is the real price of the imported inputs (IM), interest rate (PK) which is the real price of capital, wage (PL) which is the real labor price, average price of intermediate goods (PM), the whole sale price of import (PIM) which is the real price of the intermediate materials. The data are present in the following.

In table 1, all the price data are the real price of the factor and with the base of 1978 yuan, the capital price are measured by the interest rate of one year period of deposit of the according year. And for the labor, the number of the labor is the million units.

---

[11] All the data come form RTGO, Economy communiqué of Chinese government 1978~2003 Others, Chinese statistical year book, various issues

Table 1 the original date of China’s overall economy 1978-2003

Year	RTGO	RGDP	RK	L	RM
1978	5689.8	3624.1	14111.99	4.0152	2065.7
1979	6122.222	3899.53	14882.12	4.1024	2222.692
1980	6600.174	4203.96	15735.36	4.2361	2396.214
1981	6947.252	4425.03	16569.29	4.3725	2522.222
1982	7573.128	4823.68	17653.46	4.5295	2749.448
1983	8398.142	5349.17	18991.84	4.6436	3048.972
1984	9672.66	6160.97	20627.59	4.8197	3511.69
1985	10975.63	6990.89	22598.03	4.9873	3984.736
1986	11948.58	7610.61	24876.88	5.1282	4337.97
1987	13331.21	8491.27	27413.64	5.2738	4839.937
1988	14833.31	9448.03	30524.74	5.4334	5385.281
1989	15436.42	9832.18	33773.28	5.5329	5604.242
1990	16028.17	10209.09	36805.53	6.3909	5819.077
1991	17501.82	11147.73	40115.04	6.4799	6354.092
1992	19993.96	12735.09	44131.93	6.5554	7258.871
1993	22690.92	14452.91	50105.39	6.6373	8238.011
1994	25564.27	16283.08	56732.51	6.7199	9281.189
1995	27731.77	17663.66	64013.64	6.7947	10068.11
1996	30958.2	19718.73	71700.81	6.885	11239.47
1997	33683.61	21454.67	79542.5	6.96	12228.94
1998	36312.31	23129.01	87764.48	6.9957	13183.3
1999	38926.8	24794.3	96540.92	7.0586	14132.5
2000	42196.65	26877.02	108222.4	7.115	15319.63
2001	45234.81	28812.17	122507.7	7.3025	16422.64
2002	49260.71	31376.45	138678.7	7.374	17884.26
2003	54186.78	34514.1	155320.2	7.4432	19672.68

Continued table 1: (100million 1978 yuan)

year	RIM	PK	PL	PM	PIM
1978	187.4	3.24	1674	100	25.45
1979	209.6	3.37	1818	103.56	27.33
1980	278.1	4.32	1972	107.47	29.63
1981	335.4	4.35	2026	109.88	30.41
1982	459	5.32	2172	109.76	31.15
1983	649	5.49	2297	110.94	27.36
1984	817.6	4.89	2706	116.39	29.71
1985	994.9	4.77	3056	128.23	37.57
1986	1045.5	5.36	3544	134.05	44.22
1987	1083.7	6.88	3708	140.88	47.74
1988	1203.8	7.45	4314	158	47.7
1989	1279.2	8.03	4625	171.98	48.28
1990	1416.9	8.64	5266	181.68	61.39
1991	1752.6	7.56	5485	193	68.45
1992	2124.3	4.86	6011	209.17	71.24
1993	2498	4.86	6704	209.17	74.41
1994	3468.4	4.56	7736	239.64	111.53
1995	3399.5	6.32	8498	287.17	107.96
1996	3357.2	7.47	9284	324.99	107.51
1997	3401.7	5.67	9737	344.26	107.09
1998	3477.5	3.78	11447	347.07	106.88
1999	4001.6	1.98	12798	343.27	106.66
2000	5429.8	1.97	14141	345.22	106.18
2001	5808.4	1.85	16762	348.6	106.08
2002	7039.6	1.76	18934	351.2	106.07
2003	9770.2	1.73	21371	353.26	106.24

Source: RTGO, Economy communiqué of Chinese government 1978~2003

Others, Chinese statistical year book, various issues

3.1.2 The factor data

As mentioned above, the inputs factors involved in a railway production include capital, labor, imports, and intermediate items. The price indices for each variable are measured by the following equation given in 2000 prices as the base. To eliminate the effects of inflation, all variables are measured in real terms.

3.1.2.1The labor price

$$\mathrm{ipl}_i = \frac{p_{li}}{p_{lb}} \qquad i = 1978\text{-}2003$$

where:

ipl_i : labor price index for year i

p_{li} : labor price for year i,

p_{lb} : labor unit price for base year (i.e. year 2000)

The total labor costs in question are the wage expenses of all the labors in China, including the industry labor force, the agricultural labor force and so on. The size of the workforce is the total number of employee.

3.1.2.2The capital price

$$ipk=\frac{p_{ki}}{p_{kb}} \qquad i = 1978\text{-}2003$$

where:

ipk: capital price index for year i

p_{ki}: capital price for year i,

p_{kb}: capital unit price for base year (i.e. year 2000)

The capital is defined as the sum of interest and depreciation associated with the capital stock and structure capital which represent the factory workshop, the land the product facilities and so on. As these are typically long-lived, they are treated as a fixed factor. The capital denoted k, is measured as the sum of interest and depreciation associated with the fixed ones.

3.1.2.3The import price

$$ipim_i=\frac{p_{imi}}{p_{imb}} \qquad i = 1978\text{-}2003$$

where:

$ipim_i$: import price index for year i

p_{imi} : import price for year i,

p_{imb} : import unit price for base year (i.e. year 2000)

The input factor of imported materials are the materials that in the national production used and come form the foreign markets, including the raw materials that are imported, the imported energy, the imported facilities, the imported technology and so on.

3.1.2.4The intermediate material price

$$\mathrm{ipm}_i = \frac{p_{mi}}{p_{mb}} \qquad i = 1978\text{-}2003$$

where:

ipm_i : intermediate material price index for year i

p_{mi} : intermediate material price for year i,

p_{mb} : intermediate material unit price for base year (i.e. year 2000)

The intermediate material factor is the intermediate goods that the Chinese produced and used as raw material in order to produce the final output. It mainly include some of the agriculture products, the energy, the semifinished product of some industry and so on.

3.1.3 The real output factor price

$$Y_i = \frac{p_{Yi}}{p_{Yb}} \qquad i = 1978\text{-}2003$$

where:

Y_i : real gross domestic production price index for year i

p_{Yi} : real gross domestic production price for year i,

p_{Yb} : real gross domestic production price for base year (i.e. year 2000)

The total output factor which is defined as the gross domestic output (GDP), is a measure of the amount of the economic production of a particular territory in financial capital terms during a specific time period. It is one of the measures of national income and output. It is often seen as an indicator of the standard of living in a country.

3.1.4 The real total cost factor price

$$TC_i = \frac{p_{TCi}}{p_{TCb}} \qquad i = 1978\text{-}2003$$

where:

TC_i : real total gross output price index for year i

p_{TCi} : real total gross output price for year i,

p_{TCb} : real total gross output for base year (i.e. year 2000)

Due to the total gross output of the nation were consumed by the labor force or be used as semifinished product for the final production, the total gross output of the nation meanwhile is the total cost of the nation.

3.1.5 The share of factor cost

The calculation of the share of capital (SK), labor (SL), intermediate materials (SM), and import (SIM) are as follows. They are the proportion of the capital input, the labor input, the intermediate material input and the import input according to the total input of the overall economy of the nation.

$$SK = \frac{RK * PK}{TC}$$

$$SL = \frac{L * PL}{TC}$$

$$SM = \frac{RM}{TC}$$

$$SIM = \frac{RIM}{TC}$$

3.1.6 Time series index data for the model

Based on the section 3.1.2 to section 3.1.5 mentioned we converse the original data of table 1 for the translog cost function system equations to use.

Using the data of year 2000 as standard, the index of real total gross output TC, index of real GDP Y, index of interest rate K, index of wage L, index of average intermediate material mediate price M and the index of whole sale price of import IM are presented in the table 2-1 as follows.

According to the section 3.1.5 the share of the inputs (capital, labor, intermediate material, imported material) in the total cost, the share of capital (sk), the share of labor (sl), the share of intermediate material (sm), and the share of imported material (sim) in the according year are presented in the following table 2-2 .

3.2 The results of estimation

3.2.1 Parameters estimation

We estimated the system of equations consisting of the cost function, omitting the linearitly dependent intermediate material cost share equation and using the Full Information Maximum Likelihood (FIML) command to

Table 2-1 the index data for model:

year	TC	Y	K	L	M	IM
1978	0.1348401	0.0278360	1.6446701	0.2430171	0.2896704	0.2396873
1979	0.1450879	0.0302781	1.7106599	0.2568904	0.2999826	0.2573931
1980	0.1564147	0.0323949	2.1928934	0.2675584	0.3113087	0.2790544
1981	0.1646399	0.0366419	2.2081218	0.2651243	0.3182898	0.2864005
1982	0.1794723	0.0484041	2.7005076	0.274353	0.3179422	0.2933697
1983	0.1990239	0.0540692	2.786802	0.2809589	0.3213603	0.2576756
1984	0.2292282	0.0627913	2.4822335	0.3115721	0.3371473	0.2798079
1985	0.2601066	0.0794685	2.4213198	0.3360681	0.3714443	0.3538331
1986	0.2831642	0.0918478	2.7208122	0.3749629	0.3883031	0.4164626
1987	0.3159305	0.0891715	3.4923858	0.3790164	0.4080876	0.4496139
1988	0.3515282	0.1160311	3.7817259	0.4258387	0.4576792	0.4492371
1989	0.3658211	0.1390898	4.0761421	0.4509047	0.4981751	0.4546996
1990	0.3798446	0.1527514	4.3857868	0.4444854	0.5262731	0.5781691
1991	0.4147681	0.1772125	3.8375635	0.4553487	0.5590638	0.64466
1992	0.4738282	0.2322367	2.4670051	0.4890812	0.6059035	0.6709361
1993	0.5377423	0.2759041	2.4670051	0.5308237	0.6059035	0.7007911
1994	0.6058365	0.3345482	2.3147208	0.5963158	0.694166	1.0503861
1995	0.6572031	0.4325453	3.2081218	0.6386216	0.8318464	1.016764
1996	0.733665	0.5137320	3.7918782	0.6807003	0.9413997	1.0125259
1997	0.7982533	0.5922878	2.8781726	0.7034579	0.9972192	1.0085704
1998	0.8605496	0.7288164	1.9187817	0.8221642	1.0053589	1.0065926
1999	0.9225093	0.9454413	1.0050761	0.9128461	0.9943514	1.0045206
2000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000
2001	1.0720002	1.0373572	0.9390863	1.1548994	1.0097909	0.9990582
2002	1.1674081	1.0880074	0.893401	1.2918951	1.0173223	0.998964
2003	1.2841491	1.1736365	0.8781726	1.4359869	1.0232895	1.0005651

Table 2-2: the share of inputs according to total cost

year	SK	SM	SL	SIM
1978	0.0803593	0.3181223	0.5685822	0.0329361
1979	0.0819192	0.3193185	0.5645264	0.0342359
1980	0.1029924	0.3185492	0.5363231	0.0421353
1981	0.1037481	0.3095376	0.5384362	0.0482781
1982	0.1240127	0.304391	0.510987	0.060609
1983	0.1241527	0.2881784	0.5103896	0.077279
1984	0.1042825	0.2879916	0.5231989	0.0845269
1985	0.0982109	0.2832766	0.5278661	0.0906463
1986	0.1115949	0.2985273	0.5023779	0.0874999
1987	0.141477	0.2781374	0.499095	0.0812905
1988	0.1533099	0.2893516	0.4761833	0.0811552
1989	0.175688	0.2998045	0.4416385	0.0828689
1990	0.1984006	0.3287629	0.3844383	0.0884006
1991	0.1732789	0.3127349	0.4138436	0.1001381
1992	0.107273	0.29746	0.4890141	0.1062471
1993	0.107317	0.2880294	0.4945655	0.1100881
1994	0.101196	0.2907722	0.4723583	0.1356737
1995	0.1458855	0.2902575	0.4412719	0.1225851
1996	0.1730091	0.2808221	0.4377254	0.108443
1997	0.1338948	0.2696347	0.4954805	0.1009898
1998	0.113601	0.2938211	0.5190521	0.0957664
1999	0.1491053	0.3070539	0.5410468	0.1027981
2000	0.1505249	0.3127837	0.5080129	0.1286785
2001	0.1501028	0.3458518	0.4756394	0.1284055
2002	0.1495475	0.3587376	0.4488064	0.142905
2003	0.1495885	0.3659013	0.4042042	0.180306

apply maximum likelihood methods in EVIEWS (version 3.1).

Table 3 presents the estimate result for the cost function. Standard errors t-statistic and meanwhile the probability of each parameter for the cost equation are also reported in table 3.

Under the assumption of production cost minimization, in order that the cost function be well-behaved, the estimated model must be non-negative in input prices, concave in factor prices and monotonically increasing in output (Varian, 1984). Non-negativity in input price is satisfied if the cost shares of the input factors are positive. Concavity is satisfied if the Hessian Matrix of second order coefficients is negative semi-definite. Monotonicity is satisfied if the predicted costs increase as output increase (McGreehan, 1993). All three conditions are satisfied in our estimates, thus indicating the translog cost function captures well the underlying technology.

Table 3: Parameter estimates for translog variable cost function

	Coefficient	Std. Error	t-Statistic	Prob.
β_0	1.61705429074	0.377132843805	4.28775779489	5.05823289882e-0
β_k	0.1757981427851	0.100300970488	0.15750737713	0.875246876854
β_l	0.642931980882	0.0745799125384	8.88888117885	1.60336110548e-1
β_{im}	0.0651288082113	0.476656879266	0.136636668942	0.891665600615
β_y	1.51674914442	0.386401037206	3.92532368802	0.00018391124799
β_t	-0.0946127730279	0.0216985592414	-4.3603251246	3.87729333051e-0
β_{kl}	-0.0079161694293	0.0491156552601	-0.16117405718	0.872367779295
β_{km}	0.0457081790237	0.116258546316	0.39315973295	0.695260490875
β_{ky}	-0.0297834837086	0.151836008987	-0.19615560173	0.844992084501
β_{kt}	0.0016648305299	0.00388680353402	0.42832896373	0.66957720033
β_{lm}	-0.0200009205508	0.15587822916	-0.128311186614	0.898228795568
β_{ly}	-0.0039406521143	0.151568004343	-0.025999234676	0.979323512268
β_{lt}	0.0016648305299	0.00346304035925	-4.27588262556	5.28197074613e-05
β_{imy}	0.117197235283	0.17942886418	0.653168239225	0.515544302082
β_{my}	5.82240929145	0.460668926368	12.6390319776	1.15944161861e-20
β_{mt}	-0.0140542786504	0.0188485295412	-0.745643240746	0.458095833715
β_{imt}	0.00282725176051	0.02073278992	0.136366199215	0.891878702676
β_{kk}	0.079528713617	0.0213449825765	3.72587390653	0.000363860491153
β_{ll}	-0.21448547707	0.100894443501	2.12584033002	0.0366400023099
β_{mm}	-4.06541709375	0.424237035446	-9.58289058728	7.1096389318e-15
β_{imim}	-0.0145242584098	0.135181627886	0.107442547015	0.914710299859
β_{yy}	-1.9926024485	0.276302992121	-7.21165714928	2.93474225137e-10
β_{tt}	0.00103379759125	0.000482940239972	2.1406325373	0.0353877486958
β_{kim}	-0.00164585406287	0.0386403567572	-0.042594173579	0.966132512508
β_{lim}	-0.0289938568572	0.223261982834	-0.129864728823	0.897003545124
Log Likelihood		312.556566222		
Determinant residual covariance		4.25051733574e-16		

The labor cost share is positive, implying that the cost function is increasing in this input factor. The coefficient of capital stock is positive. This result indicates, contrary to what is normally expected in cost theory that a marginal increase in the capital stock results in small raises in variable cost. And, since total cost and the regressors are in logarithms and have been normalized, the coefficients are interpretable as cost elasticities. The output elasticity is positive and implies that an increase in the production will raise the variable cost. An 1% increase in the quantity of GDP will increase the variable cost by approximately 1.5%

3.2.2 Features of input factors

According to the result of table 3 parameter estimates for translog variable cost function of the China's overall economy 1978-2003. From the table below the capital and intermediate material, the intermediate material and the imported material are substitutes with respect to each other, while others are not. The own elasticity of inputs has negative sign, it indicates that all the other three inputs to their own prices is low, especially the intermediate material factor, demand for these three inputs are price-inelastic.

Table 4: Elasticities of Substitution for China's economy cost function

	capital	labor	Intermediate material	Import material
Capital	-0.07953	-0.007916169	0.045708179	-0.001645854
labor		-0.214485477	-0.020000921	-0.020000921
Intermediate material			-4.065417094	0.093348019
Import material				-0.014524258

3.2.3 Technical change, economies of scale, and total factor productivity

According to the table 3, using the method provide above, we can calculate the technical change process and the change of economies of scale of the Chinese economy, and the results are presented in the following Table 5:

Table 5: technical process and economies of scale of China's economy

year	TP	ES	year	TP	ES
1978	0.056	1.034	1991	0.060	0.936
1979	0.066	0.956	1992	0.058	0.822
1980	0.056	0.938	1993	0.059	0.834
1981	0.058	1.125	1994	0.059	0.872
1982	0.055	0.988	1995	0.061	0.983
1983	0.053	0.832	1996	0.053	1.062
1984	0.057	0.945	1997	0.060	0.997
1985	0.058	0.837	1998	0.052	1.032
1986	0.053	1.003	1999	0.061	0.932
1987	0.06	1.024	2000	0.056	0.951
1988	0.055	0.998	2001	0.067	0.922
1989	0.052	1.103	2002	0.064	0.937
1990	0.054	1.065	2003	0.060	0.928
average		**TP**	**0.058**	**ES**	**0.964**

First, let’s turn to the question of technological progress, in the table 3, the data indicates that there is evidence of a large negative time shift of the variable cost function. Thus the negative coefficient of T indicates that the China’s economy underwent large progressive technical change during the period considered in the analysis. In the followed table, table 5, the yearly technical change progress is presented, in the year 1978 to 2003 the average technical change rate is 5.8%. Technical change plays an important part in the growth of Chinese economy.

Second, we turn to the growth of Chinese economies of scales. The numerical value of ES indicates the returns to scale. If the numerical value of ES is larger than 1, then the diseconomies of scale exist, if the numerical value of ES is smaller than 1, then economies of scale exist, if the numerical value of ES equals 1, then constant returns to scale exist. And the numerical value of ES is found to be 0.964 indicating that small economies of scale exist in the China’s overall economy.

And third, after combining the technical change rates with efficiency change rate, we obtain TFP growth rates with the result form fixed effects model. And the results of Chinese total factor productivity change are presented in the following table, table 6. In the period of 1978 to 2003, the average TFP growth rate is 14.7%.

Table 6: Total factor productivity growth of China.

period	TFP	period	TFP
78-79	0.139	91-92	0.175
79-80	0.129	92-93	0.171
80-81	0.117	93-94	0.169
81-82	0.144	94-95	0.144
82-83	0.144	95-96	0.176
83-84	0.200	96-97	0.148
84-85	0.171	97-98	0.133
85-86	0.142	98-99	0.128
86-87	0.178	99-00	0.136
87-88	0.167	00-01	0.133
88-89	0.097	01-02	0.147
89-90	0.095	02-03	0.153
90-91	0.146		
average		**0.147**	

4 Conclusion

This paper discusses the technical progress, the economies of scale and the total factor productivity of the Chinese economy during the period of year 1978 to 2003 using the translog cost function. And in the process this paper also estimated elasticity of the input factors to how they acted in the Chinese economy. We know that the capital and intermediate material, the intermediate material and the imported material are substitutes with respect to each other, while others are not. The own elasticity of inputs are negative sign except the capital one, it indicates that all the other three inputs to their own prices is low, especially the intermediate material factor, demand for these three inputs are price-inelastic.

In this study, Firstly, this study has confirmed the cost structure of the China’s economy is labor-intensive, material-intensive and capital-saving natures. And in the year 1978 to 2003 the average technical change rate is 5.8%. Technical change plays an important part in the growth of Chinese economy. Meanwhile the numerical value of ES is found to be 0.964 indicating that small economies of scale exist in the China’s overall economy. When we combine the technical change rates with efficiency change rate, the total factor productivity growth rate can be calculated, and the average rate is 14.7%.

In conclusion, even through Chinese economy is still the labor intensive economy, it is experiencing a rapid technical change and growth of economies of scale, the total factor productivity grows rapidly and steadily.

Reference

[1] Barro, R.J.; Sala-I-Martin, X., (1995) *Economic Growth* McGraw-Hill, Inc.

[2] Battese, G.E.; Coelli, T.J. (1995) "A Model for Technical Ine±ciency E®ects ina Stochastic Frontier Production Function for Panel Data" *Empirical Economics*,20(2), 325-32.

[3] Caves, D.W., L.R. Christensen and W.E. Diewert. (1982a) "Multilateral Com-parisons of Output, Input and Productivity Using Superlative Index Numbers "*Economic Journal,* 92, 73-86.

[4] Caves, D.W., L.R. Christensen and W.E. Diewert. (1982b) "The Economic The-ory of Index Numbers and the Measurement of Input, Output and Productivity"*Econometrica,* 50, 1393-1414.

[5] Chambers, Robert G. (1988) *Applied Production Analysis* Cambridge UniversityPress.

[6] Coelli, T.; Rao, D.S.P.; and Battese, G.E.. (1998) *An Introduction to E±ciencyand Productivity Analysis* Kluwer Academic Publishers.

[7] Diewert, W. Erwin (1976) "Exact and Superlative Index Numbers." *Journal of Econometrics,* 4:115-45.

[8] Ezaki, Mitsuo, and Sun, Lin. (1999) "Growth Accounting in China for Na-
tional, Regional, and Provincial Economies: 1981-1995." *Asian Economic Journal,*13(1),39-71.

[9] Fulginiti, Lilyan E., and Perrin, Richard K. (1993) "Prices and Productivity in Agriculture." *The Review of Economics and Statistics*, 75(3), 471-482.

[10] Fulginiti, Lilyan E., and Perrin, Richard K. (1997) "LDC agriculture: Nonpara-metric Malmquist productivity Indexes." *Journal of Development Economics,* 53,373-390.

[11] Fare, R., S. Grosskopf, M. Norris and Z. Zhang. (1994) "Productivity Growth, Technical Progress, and E±ciency Changes in Industrialised Countries." *American Economic Review,* 84, 66-83.

[12] Griliches, Zvi. (1994) "The Residual, Past and Present: A Personal View."
unpublished paper,Harvard University.

[13] Kalirajan, K. P.; Obwona, M. B.; Zhao, S. (1996) "A Decomposition of Total Factor Productivity Growth: The Case of Chinese Agricultural Growth before and after Reforms." *Journal of Agricultural Economics,* 78(2), 331-38.

[14] Krugman, P. (1994) "The Myth of Asia's Miracle." *Foreign A®airs,* 73(6).

[15] Li, W. (1997) "The Impact of Economic Reform on the Performance of Chinese State Enterprises, 1980-1989." *Journal of Political Economy,* 105(5), 1080-1106.

[16] Mankiw, G. N., Romer, D. andWeil D. N. (1992) "A Contribution to the Empirics of Economic Growth." *The Quarterly Journal of Economics,* 107, 407-437.

[17] Putterman, L.; Chiacu, A.F. (1994) "Elasticities and Factor Weights for Agri- cultural Growth Accounting: A Look at the Data for China." *China Economic Review,* 5(2),191-204.

[18] Romer, D. (1996) *Advanced Macroeconomics* McGraw-Hill, Inc.

[19] Solow, Robert M. (1957) "Technical Change and the Aggregate Production Function." *Review of Economics and Statistics,* 39 (August), 312-320.

[20] SSB (State Statistical Bureau of China). (1989-1998) *Statistical Yearbook of*
China, 1989-1998 The Statistical Publishing House, Beijing .

[21] Thornqvist, Leo. (1936) "The Bank of Finland's Consumption Price

Index." *Bank of Finland Monthly Bulletin,* no.10, 1-8.
[22] Woo, Wing-Tye. (1996) "Chinese Economic Growth: Sources and Prospects."
University of California, Davis, Department of Economics Working Paper, 96/08, May 1996.
[23] Wu, Yanri. (1999) "Productivity and E±ciency in China's Regional Economies." *Economic effciency and productivity growth in the Asia-Paci¯c region,* Academia Studies in Asian Economies, 1999, pages 171-90.
[24] Young, A. (1995) "The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience." *The Quarterly Journal of Economics,* August 1995, 641-680.
[25] Young, A. (2000) "TGold into Base Metals: Productivity Growth in the People's Republic of China during the Reform Period." *NBER Working Paper*, No. W7856.