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Has Productivity Contributed to the Economic Growth of Yangtze River Delta?

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April 2010

Abstract

The principal target of my thesis is to identify the sources of economic growth in YRD zone. A review of YRD post-reform development is conducted. The empirical study examines total factor productivity growth, technical progress, efficiency change and the scale effect in 16 component cities in YRD. Panel data of 1985-2007 are analyzed by using the stochastic frontier model. The major issues consider as (1) analyzing the source of YRD growth in which productivity growth is decomposed into three components: technical progress, changes in technical efficiency and the scale effect, (2) comparing the productivity and efficiency performance among cities and finding the tendency between the results from different parts of TFP growth, and (3) providing the explanation for my estimation and policy implication. YRD's growth has been mostly input-driven and TFP growth by average 9.5% each year. For sustaining the engine position in China, YRD should take effort to enhance the technology level and introduce in technical innovation from outsides.

INDEX WORDS: Productivity growth, Sources of productivity growth, Efficiency change, Technical change, Scale effect, Stochastic frontier analysis.

Abbreviations

CES	Constant Elasticity of Substitution
CRS	Constant Return to Scale
DRS	Decreasing Return to Scale
IRS	Increasing Return to Scale
JS	Jiangsu
SE	Scale Effect
SEZs	Special Economic Zones
SOEs	State-owned Enterprises
TE	Technical Efficiency
TP	Technical Progress
TVEs	Township and Village Enterprises
YRD	Yangtze River Delta
ZJ	Zhejiang

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Chapter 1

Introduction

1.1 Background of Research

Yangtze River Delta (YRD in short), also called as Chang Jiang Delta, is situated in east China and generally includes the city of Shanghai, Jiangsu province, and Zhejiang province. It used to be a transportation and agriculture center in ancient China and has become emerging economic engine in China recent years. As one of China's economic powerhouse, Yangtze River Delta has maintained its leadership position for several years, with growth rate ahead the national level. In 2007, the region reported a GDP of RMB4667.2 billion with an increase of 14.8%, 2.9% higher than the national growth rate. With less than 2% of the country's land area and 6.3% population, the aggregate GDP of the region contributed to 22.5% of China's total.

The remarkable economic growth in YRD benefits from the precious chance of reform and opening-up in China. Before the reform period, YRD is similar with other regions which was strictly controlled in planned economy system. Foreign trade was almost banned except some communist countries. With China's foreign trade quadrupling in value, YRD generally became an important manufacture basis and most of products are exported to other countries. Now, YRD is accredited as the biggest export region in China. Geographically, the metropolitan circle of the Yangtze River Delta is located on the eastern coast of China, which is geographically considered as the golden region, with a pleasant climate, convenient land and ocean transportation and plentiful surplus labor. Shanghai, as the heart of YRD, has an ambition to become the Asian, even the world financial center.

The spectacular rate of economic growth in China has attracted considerable interest from economists, policymakers and scholars. The success of China reform is similar with the economic takeoff of some East Asia countries. Many scholars called the takeoff process in East Asia countries as "miracle" or "myth". Whether the remarkable economic growth in East Asia countries could be sustainable and how much productivity growth accounted for the East Asia "miracle" have induced impassioned debates among economists. Young (1994) indicated that the major source of economic growth for the "tigers" should not be attributed to productivity increases. His founding is that the "miracle" of economic growth largely benefited from capital contribution, particular in Singapore, which experienced amazing economic growth while recording negative rate of technology progress. Krugman (1994) also clarified his criticism of China that the exception rate of growth was to be expected just due to capital accumulation rather than technology progress. He called the East Asian miracle a "myth" because he believed that the diminishing returns of inputs, combining with the low rate of technology progress, is hard to sustain the high rate of growth in respective countries.

Economic growth can be attributed to either growth of inputs or growth by productivity change. In his seminal work, Solow (1957) proposed that during the period 1909-1949 there existed a large difference between output and input growth for the U.S. economy. The "residual", Solow called as "TFP" (total factor productivity) which includes all unexplained sources of growth. In earlier studies, technical progress has been widely considered as TFP because some research approaches assume a CRS technology and perfect competition in input and output markets despite it would not be accorded with reality to simplify calculation. TFP growth can be defined as the ratio of aggregate output growth to aggregate input growth, or the difference between output and input growth in logarithmic form.

1.2 Significance of Research

Previous studies on China's economic growth analysis are mainly concentrated on the aggregate national or provincial level, leaving space for further studies at the regional or city level. Studies concerning YRD productivity analysis is rare not to say in the city level. In fact, people always confuse about two definitions: YRD economic circle and YRD district. The former refers to 16 cities which are officially defined as the component cities in YRD economic circle. The latter is just a geographic term including Shanghai, Jiangsu province and Zhejiang province. It is rather difficult to collect the economic data in 16 cities so that studies analyzing the city-level productivity performance is rare. Some studies, like YRD development reports from Nanjing University, put their attention on YRD district.

My research aims for panel data analysis. Thus, the discussions about YRD in thesis are YRD economic circle. I call YRD for short.

My thesis attempts to build upon existing literatures and analyze the source of economic growth of the Yangtze River Delta since 1985. I use city-level panel data and stochastic frontier model to calculate the contribution of TFP and decomposed it into three parts: technical efficiency, technical progress and the scale effect.

1.3 Research Objective

The objective of this study is to understand the underlying growth dynamics of the Yangtze River Delta and its component cities during the period 1985-2007. In particular, it focuses on addressing the following questions:

1. Analyze whether the reform and opening policy brings the positive impacts on the living standard of the Yangtze River Delta and the importance of Yangtze River Delta for China.

2. Since a tremendous economic growth has been experienced in the region, what are its sources of growth? Investigate whether the tremendous growth is mainly derived from factor accumulation or productivity growth.

3. Using the stochastic frontier approach to calculate technical progress, technical efficiency and scale effect in cities of YRD. Using the results derived by our model to analyze the economic growth and productivity performance in YRD.

1.4 Structure of Thesis

The structure of the thesis is outlined as follows:

Chapter 2 presents an overview of reform history in YRD zone. This chapter briefly introduces the process of YRD economic circle establishment and the dazzling achievement during the reform period. Meanwhile, a summary of the discussion on two development strategies (South Jiangsu pattern and Wenzhou pattern) is also provided.

Chapter 3 provided the literature review of productivity analysis in China and other countries in East Asia. The efficiency improvement and decomposition in TFP will be illustrated by graphs.

Chapter 4 details a brief overview of the techniques of productivity analysis and introduces the model in my research. Is the principle sources of YRD's post reform input driven or technology advancement? My investigation is accomplished with this problem by adopting stochastic frontier approach and the maximum likelihood approach is used for estimation of the parameters.

Chapter 5 discusses the data that were collected and the variables that were selected for the empirical work. The sources and measurement of data are also provided. The initial capital estimate is a key for my research. I will compare with different approaches and pick up one suitable model to calculate the initial capital.

Chapter 6 discusses the empirical results, with a focus on how to answer the questions in objective. Certainly, TFP growth can be decomposed into three parts: technical progress, efficiency improvement and the scale effect. I will present each part of TFP in YRD and respective cities.

Chapter 7 contains the concluding remarks and the supplemental explanations to the final result of my research. Meanwhile, I will also give some explanations for relative high TFP growth in YRD.

Chapter 2

The Economic Takeoff of Yangtze River Delta

2.1 The March Toward Reform

Reform of 1978 firstly based on economic field, focusing on the adjustment of agriculture policy, free market formation and economic liberalization. For regional development, center government adopted the disequilibrium strategy, giving the coastal area in eastern China the priority and policy support. In 1980, four southern coastal cities (Shantou, Shenzhen, Xiamen and Zhuhai) were designated as "Special Economic Zones" (SEZs). These cities were given autonomy to experiment with new policy and exempted from many restrictions on attracting foreign investment.

Compared with SEZs, the takeoff of Yangtze River Delta is relative late. In 1982, Chinese government decided to establish the Shanghai Economic Zone. Shanghai Economic Zone firstly included 10 component cities that are Shanghai, Suzhou, Wuxi, Changzhou, Nantong, Hangzhou, Jiaxing, Huzhou, Ningbo and Shaoxing, which was then regarded as the rudiment of Yangtze River Delta Economic Circle.

In April 1990, opening of Pudong in Shanghai symbolled the takeoff of Yangtze River Delta. Shanghai, remarked as the regional financial and shipping center, takes the geographic and policy advantage to attract foreign investment and develop financial market. Peripheral cities use capital and port from Shanghai to

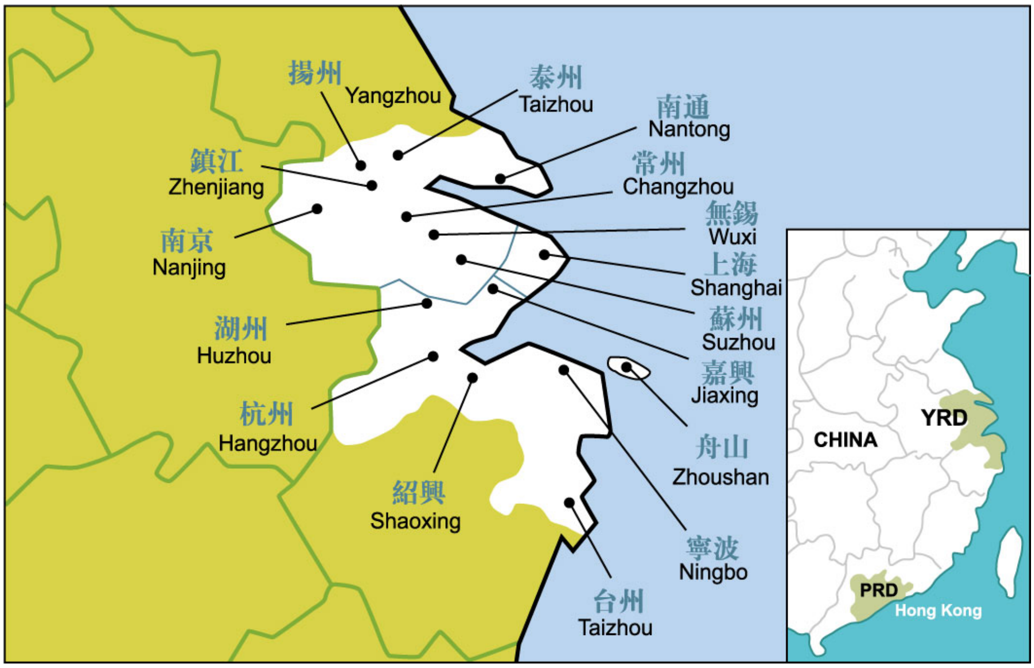

Figure 2.1: 16 Component Cities in Yangtze River Delta

develop manufacture and export industries. After several years development, the timing of establishing a more tight economic organization has become mature. In 1997, the first Yangtze River Delta Cities Economic Coordination Conference was convened in Shanghai. Unlike the previous Shanghai Economic Zone, the YRD Coordination Conference is a spontaneous association by local governments. Initial members included Shanghai, 7 cities in Jiangsu province and 6 cities in Zhejiang province which is the so-called "Yangtze River Delta Economic Circle". Taizhou (JS) separated from Yangzhou in 1995 and automatically became the member of YRD. Taizhou (ZJ) was accepted on 4^{th} coordination conference in 2005. Thus, officially, the Yangtze River Delta Economic Circle covers the area of 16 cities above prefecture level of Shanghai, Jiangsu and Zhejiang Provinces. The 16 cities are Shanghai, Nanjing, Suzhou, Changzhou, Zhenjiang, Nantong, Yangzhou, Wuxi, Taizhou(JS), Hangzhou, Ningbo, Jiaxing, Huzhou, Shaoxing, Zhoushan and Taizhou(ZJ).[1] It covers approximately 109 square kilometers and is home to about 85 million residents.

[1]The English name for these two cities are same but the pronunciation by Chinese are different. I distinguish them by each located province.

2.2 The growth of Yangtze River Delta

In China there exists three important regions which are Pearl River Delta, Yangtze River Delta and the Bohai Ring. Among three regions, YRD have the largest aggregate amount of economy and biggest contribution to national economy. Table (2.1) shows that the contribution of YRD to national economy has been raising since 1990. Until now, YRD's aggregate amount of economy has taken up nearly one quarter of national economy. Which contribute to the YRD's growth during the reform period? I conclude four main reasons.

Table 2.1: 1985-2007 Brief Information of Yangtze River Delta Economy

Year	YRD GDP (100 million yuan)	National GDP (100 million yuan)	The share of YRD to nation (%)
1985	1203	9016	13.34
1986	1362	10275	13.26
1987	1580	12058	13.10
1988	2000	15043	13.30
1989	2166	16992	12.75
1990	2433	18547	13.12
1991	2883	21618	13.34
1992	3767	26638	14.14
1993	5217	34634	15.06
1994	7008	46759	14.99
1995	8815	58478	15.07
1996	10311	67885	15.19
1997	11613	74463	15.6
1998	12658	78345	16.16
1999	13681	82067	16.67
2000	15279	89442	17.08
2001	16981	95933	17.7
2002	19125	104791	18.25
2003	22803	116694	18.54
2004	28775	159878	19.00
2005	33963	183868	19.47
2006	39613	210871	19.78
2007	46672	257306	22.51

Source: Calculated by the author

Firstly, YRD has predominate economic structure and initial conditionals when the reform started. Sachs and Woo (1994) have argued that transition economies are more likely to succeed in an underdeveloped (under-industrialized) economy with a huge surplus rural labor force and a higher proportion of primary industry.

In 1980s, two new-fashioned development strategies were derived from Jiangsu and Zhejiang provinces respectively, that are ”South Jiangsu pattern” and ”Wenzhou pattern”. The movement of low-productivity agricultural labor into high-productivity TVE activities is the primary cause of YRD growth.

A second factor was attributed to YRD's integration into the global economy. Nowadays, domestic market in China has not taken up the primary position for Chinese products. Chinese manufacture industry largely depended on global market. Upon the expanding global market, enormous demand for labor-intensive manufactured goods accelerated the movement of labor out of rural area to high productivity industry. The advantage of transportation links attracted large amount of foreign direct investment (FDI).

A third contributing factor has to do with the issue of timing. Chinese reform, which is so-called ”Socialism market economy with Chinese Characteristics” allowed state-owned industries to get rid of government control and independently assume the risk and losses. Foreign and private capital are permitted to plug into national economy. Kwan (2007), the reform on property rights granted institution recognition to TVEs and private enterprises.

The last major source of growth resulted from the rising of Shanghai, which has ambition to become the Asian even global financial center. In 1990s, Pudong development started. Shanghai accelerated its pace to establish the Chinese financial and shipping center. Peripheral cities use foreign capital and shipping advantage from Shanghai to develop their manufacture and service industries.

2.3 Comparison with two different strategies

In the development history of YRD, there always existed a controversy about two different development strategies that are South Jiangsu pattern and Wenzhou pattern. South Jiangsu pattern intended to promote TVEs while Wenzhou pattern to develop private enterprises. The typical cities of South Jiangsu pattern are like Suzhou, Wuxi, Changzhou and Zhenjiang while cities by Wenzhou pattern are Hangzhou, Ningbo and Shaoxin. From table (2.2), the cities which originally adopted two strategies had relative higher economic output. On the other hand, this has proven that both of strategies are successful and follow the right tendency

Table 2.2: 2003 The Economic condition about cities in YRD

Region	GDP (100 million yuan)	The share in YRD (%)
Shanghai	6250.81	27.41
Nanjing	1576.33	6.91
Suzhou	2801.56	12.29
Yangzhou	647.22	2.84
Zhenjiang	641.05	2.81
Changzhou	901.42	3.95
Wuxi	1901.22	8.34
Nantong	1006.71	4.41
8 cities in Jiangsu	10055.55	44.1
Hangzhou	2099.80	9.21
Ningbo	1786.85	7.84
Huzhou	490.75	2.15
Jiaxin	858.03	3.76
Zhoushan	172.47	0.76
Shaoxin	1089.28	4.78
6 cities in Zhejiang	6498.98	28.49
Total GDP in YRD	22803.34	

Source: *Yangtze River Delta Development Report 2005*

of reform.

TVEs are a collective-ownership structure which is leaded by local governments. The local officials provide the related produce materials, like land, capital and labors, construct the workshop and appoint managers to be in charge of the business affairs. In institution, government officials have no right to intervene the daily affairs in TVEs. This organization pattern effectively combined with entrepreneurs and social unused capital, quickly surmounted the period of primitive capital accumulation, and absorbed huge amount of labor from rural area. Although the impact of government can not be avoided, TVEs were also regards as effective pattern in the transition period of the planned economy switching to the market economy.

Up until 1990s, private ownership in China was almost prohibited. TVEs had the absolute comparative advantage in that period. Chang and Wang (1994) believe that collective ownership was not a result of a superior system, which could be regarded as a semi-finished product during the transition of Chinese economy. Unlike SOEs, TVEs have more operational flexibility and fewer social welfare burdens. For instance, they can hire and fire employees without state approval and not worry about the retire personnel. Despite these merits, the role of TVEs began to diminish in 1990s. Private enterprises became another engine of YRD growth.

Compared with private enterprise, TVEs have some shortcomings. The first is that collective ownership can not get rid of problems with SOEs that political intervention could seriously hurt the normal operation of TVEs. Managers and employees have no stimulation to enlarge production because of lacking incentive mechanism. Secondly, TVEs are hard to define the property rights. The third problem can be attributed to limited managerial control. Enterprise managers normally appointed by local government. Thus, TVEs operation may be controlled to meet the target of government not the demand of market.

Private enterprises strategy is renowned Wenzhou pattern which brings the fresh vigor into national economy and increases production efficiency. As a former prohibited economic style, Chinese private enterprises also created dazzlingly achievement and developed their own unique way. Despite of existing irregular trade, malevolent competition and high risk, Chinese private enterprises have becoming mature in recent years. The change of economic environment also forced the TVEs to carry out reform. The primary target of this reform is to separate the relationship between government and TVEs. As matter of fact, the reform made the South Jiangsu pattern and Wenzhou pattern converges.

Chapter 3

Literature Review and Productivity Analysis

In order to realize the economic growth and gain the proper prospective on YRD's growth over two decades, it is necessary to not only review literature regarding China, but also to compare China's achievement to the other countries, like NICs. Different views concerning the major source of total factor productivity growth are listed.

3.1 Literature Review

3.1.1 International Studies

After World War II, the whole world has achieved unprecedented high rates of growth. The compelling economic miracle has attracted lively debates among economists and social commentators. Numerous researches are trying to explain the source of growth in these countries. The ground-breaking works about technology progress and TFP analysis is presented by Solow. Solow (1957) found that factor accumulation could not explain all growth, 80% of per capita income growth in the United States during 1909-1949 causing by technological progress, leaving one-eighth the result of factor accumulation when he took the research on U.S.

Despite a large volume of literature, there has been no consensus on the sources of growth in East Asia. In one of the first studies focusing on East Asia, Chen

(1977) conducted a thorough productivity analysis of Japan, Hong Kong, Korea, Singapore and Taiwan for the year 1955-1970. He found that average annual TFP growth are ranging from 3.6% to 5.6%. TFP growth accounted for roughly two-thirds of all agricultural growth, while growth in manufacturing was primarily input driven.

Young (1992, 1994 and 1995) present a different view on the performance of the four East Asian “tigers”. Young (1994) estimated TFP growth for about 118 countries, including the four East Asian “tigers” and the OECD countries. For the period 1970-1985, Young found that despite of their extraordinary high GDP growth, the“tigers” realized productivity growth rates close to average value of sample, 2.5% of productivity growth rate for Hong Kong, 1.5% and 1.4% for Taiwan and South Korea respectively; But surprisingly, the TFP for Singapore are estimated only for 0.1%. The findings on Hong Kong and Singapore are consistent with the results from Young’s (1992) paper on two cities, Hong Kong and Singapore. The author in his paper (1992) showed that these two cities have had significant increases in labor participation rates and capital investment, and suggested that the high growth rates in the 1960s to 1980s are mainly caused by factor accumulation. Young (1995) examined the sources of economic growth of the four East Asian “tigers”. Using a methodology similar to that in Young’s (1992), Young (1995) showed findings consistent with his previous studies that Singapore experienced almost no growth in TFP, with the average annual TFP growth of 0.2% for the year 1966-1990. The three papers by Young was trying to certify that even though the “tigers” had experienced extraordinary high output growth, their TFP growth rates were non-distinguishing.

Kim and Lau (1994) also present their research regarding the sources of economic growth in the East Asian countries. The study compared the major sources of economic growth between four East Asian countries and five industrialized countries. The meta-production function model was used to analyze. In this paper, the authors assume a hypothesis that there is no technical change in the postwar period. The hypothesis was rejected for the industrialized countries but could not rejected for the group of East Asian economies. Adopting the same approach, Kim and Lau (1996) extend the study of economic growth analysis by including China, Indonesia, Malaysia, the Philippines and Thailand. They concluded that capital input growth would be the major source of economic growth to the East Asian countries.

Lau and Park (2003) revisited the source of East Asian economic growth. After enlarging the sample period, they found evidence of positive measured technical progress in some of the East Asian developing economies. The importance of tangible capital as a source of growth in the East Asian developing economies should declining, which is gradually supplanted by intangible capital.

The findings of Young's (1992, 1994) and Kim and Lau's (1994) were popularized by Krugman's (1994) controversial article comparing the growth of East Asia to that of the Soviet Union and its demise in the 1990s. Krugman warned that it is impossible to sustain economic growth over time by continually augmenting inputs, since inputs are subject to diminishing returns. That is, zero growth in total factor productivity may actually pose an obstacle to a country's long-run growth; A country such like Singapore, which is documented to realize nearly zero total factor productivity growth, would eventually face the limits to its input expansion and consequently follow Russia's footsteps in experiencing slower growth.

3.1.2 China Studies

Few people would doubt about China's extraordinary growth performance since reforms started in 1978, but the source of the growth have attracted lots of heated debates. Unlike studies on East Asia, the research on China must overcome the trouble of data. Most of data we can find are based on the reports or yearbooks of officials. In the initial period of reform, officials are rewarded by superior performance and punished by failing to meet targets. Thus, Young (2003) believed that the local governments have a motivation to modify their statistical data for policy objective. The national income statistics need to do some adjustments and then be used for research. However, Chow (1993) argue that he chose to trust Chinese statistics. Different views on the reliability of Chinese statistics could lead to different estimate results of Chinese productivity.

Li (1992) calculated the contribution of labor, capital and total productivity growth for 38 years. The calculation and analysis are based on the national accounting system (NAS) because the benchmark year of statistic system reform started from 1993. In his paper, the sources of China's economic growth are mainly driven by capital and labor inputs. During the period of 1953-1990, the contribution of capital input was 75.07%, contribution of labor input was 19.47% and the contribution of productivity was only 5.46%. TFP contribution rates gave the China strong economic strength and made a good foundation for modernization.

Using the finding of Li (1992) as reference, Borensztein and Ostry (1996) compared the performance of the pre- and post-reform periods. They found that the growth rate of TFP was negative before reform, attributing to the very low initial capital-stock, but after reform period, China recorded average 3.8% per year. When come to the question of whether China's current rate of growth is sustainable? They maintained that increase in productivity generated by the reform may slow down. The labor allocation from the rural into other sectors is likely to taper off in the near future and maintenance of high productivity growth will thus be essential to achieving continued rapid growth in China.

Wu(1995) examined TFP growth using stochastic frontier model. Production function are estimated for state industry, rural industry and agriculture from the period of 1985-1991. The author compared productivity and efficiency performance among regions as well as across the sectors. In a later study, Wu (1997) sought to explain the average yearly growth rate for GDP of about 10% during the period 1980-1992. He extended his work by examining regional production and efficiency and employed the usual stochastic frontier production approach, allowing for time-varying and firm-specific technical inefficiency. Wu (2008) revisited the debate about the role of productivity in economic growth in China and extended the period to 1992-2004. It is found that growth in China has largely been driven by factor inputs. TFP growth tends to play a positive role in economic growth, accounting for average 27% of economic growth during 1993-2004. It is also found that China is yet to catch up with the world's best practice in which technological progress is the main driver of economic growth. To sustain current growth momentum, China should deepen its economic reform and narrow the gap between the coastal and interior areas.

The influential works by Chow (1993) provided an empirical estimate of Cobb-Douglas production functions for China and for five sectors. The five sectors are agriculture, industry, construction, communication and commerce. In this paper, Chow estimate initial capital stocks in the five sectors and use the aggregate capital stocks to plot the relationship between $\ln(Y/N)$ and $\ln(K/L)$. It is surprisingly found that the points fell below the straight line with a slope of about 0.6. Chow and Lin (2002) updated Chow (1993) and certify the capital and labor elasticities are respectively 0.6 and 0.4.The ratio of capital and labor is later challenged by Holz (2006) who used the different way to estimate of capital. Chow (2006)responded for Holz's doubt and deemed the initial value of capital stock estimated by Holz is unreasonable. Chow (2008) supported the conclusion that the rate of increase in TFP in China was zero before 1978 and was about 0.027 per year afterwards and the capital elasticity of output was about 0.6% and the labor elasticity was about 0.4.

The studies by Borensztein and Ostry (1996), Chow (1993) and Wu (2000) did not incorporate human capital as an input in their aggregate production function. Thus, their measurement of productivity growth suffered from an omission bias. Wang and Yao (2002) were trying to construct annual measures of human capital stock for the period spanning 1952-1999. With human capital being incorporated, the growth of TFP was contributed positively to output growth in the reform period, accounting for 25.4% of growth in 1978-1999 while it was negative for per-reform period. Fleisher, Li and Zhao (2007) also used the human capital by their unique approach. They considered that FDI had much larger effect on TFP growth before 1994. After 1994, its effect becomes much smaller or statistically insignificant. Human capital positively affected output by the increase in high education enrollment rate and domestic innovation activities.

Alwyn Young (2003) adjusted the data for 1978-1998 and constructed alternative data series and deflators to calculate TFP. Young calculated the aggregate and nonagricultural economic statistics. Using the official data, TFP should be 3% per year while it is 1.4% adopting the approach by Young.

3.1.3 Summary

The empirical works above demonstrate that TFP, which is explained as the residual of measurement, remains a driving force for long-run economic growth. East Asia economic miracle was undoubtedly splendid but actually the economy growth of these countries, as Krugman reported, is not sustainable due to diminishing returns to capital. Mr. Zheng yuxin deem that TFP making a more significant contri-

Table 3.1: A Selected Summary of Literature on Economic Growth and Productivity Analysis (foreign countries)

Author	Economies	Period	Findings
Abramovita (1956)	U.S.	1869-1904	TFP contribution: 90%
Solow (1957)	U.S.	1909-1949	TFP contribution: 80%
Chen (1977)	Four "Tigers" in East Asia	1955-1970	TFP growth between from 3.6% to 5.6%
World Bank (1993)	1)Hong Kong	1960-1989	TFP growth: 4.2%
	2)South Korea	1969-1989	TFP growth: 3.5%
	3)Taipei	1960-1990	TFP growth: 3.8%
	4)Japan	1960-1990	TFP growth: 3.5%
Young (1992)	Singapore & HK	1966-1990	No growth in TFP
Young (1994)	118 countries	1970-1985	Hong Kong: 2.5%, Taiwan:1.5%
			South Korea: 1.4%, Singapore: 0.1%
Young (1995)	Four East Asian "tigers"	1966-1990	TFP in manufacturing industry
			of singapore was -1%
Kim and Lau(1994)(1996)	East Asian countries	1966-1990	No technical change in the postwar period
Lau and Park(2003)	East Asian countries	1966-1995	Tangible capital decline, tangible capital increase
Barro and Martin(1992)	1)48 U.S.states	1)1840-1988	1)Strong evidence of convergence in per capita
	2)98 countries	2)1960-1985 S&H data	2)No evidence of convergence
	3)20 OECD countries	3)1960-1985 OECD	3)Evidence of convergence in per capita GDP

Source: Compiled by the author.

Table 3.2: A Selected Summary of Literature on Economic Growth and Productivity Analysis (China)

Author	Production function	Period	Findings
Li, Jinwen (1992)	Translog production function	1953-1990	TFP contribution: 5.46%
Borenstein	Growth accounting	pre reform	pre-reform TFP is negative
and Ostry (1996)		post reform	post-reform TFP rose to 3.8%
Wu Yanrui(1995)	Frontier production function	1985-1991	TFP growth between from 3.6% to 5.6%
Wu Yanrui(2000)	Frontier production function	1982-1995	TFP growth rate decline from 1.2% to 0.2%
Wu Yanrui(2003)	Frontier production function	1985-1997	TFP growth rate: 1.4%
Wu Yanrui(2008)	Frontier production function	1992-2004	TFP account for average 27% economic growth
Wang and Yao (2002)	Cobb-Douglas production function	1952-1999	TFP contribution: 7% (capital share: 0.33)
	incorporate human capital		TFP contribution: 5% (capital share:0.4)
Fleisher, li	Cobb-Douglas production function	1978-2003	FDI had large effect on TFP growth
and Zhao (2007)			before 1994
Chow (2008)	Cobb-Douglas production function	1952-2005	Before 1978, zero TFP growth
			After 1978, 0.027 per year increase in TFP
Alwyn Young(2003)	Cobb-Douglas production function	1978-1998	TFP should be 3%
	Unique approach to deal with official data		TFP is 1.4% by Young data

Source: Compiled by the author.

bution to economic growth only happened in the steady growth period. Although we regarded TFP as the very important factor for sustainable development, most of countries which devote to make economic takeoff are only able to adopt the strategy to increase capital accumulation and population in the first time. Thus in that period, TFP of these countries are destined to stand at low level. Countries in East Asia are outstanding examples. The developed countries, like U.S and Japan, have a relative higher contribution of TFP because these countries have experienced hundreds of years of development and their economy growth is in a relative steady phase.

Additionally, TFP is calculated as the residual in the classic growth accounting. The residual is sometimes interpreted as a measurement of the contribution to economic growth other than capital and labor. The definition of TFP is so broad that it is difficult to clarify which factors should be included in TFP. Thus, the measurement error for TFP estimation is insurmountable. Certainly, different approaches may lead to different results of TFP estimation. For instance, different models or different capital estimation may cause different results of TFP for same period. Some empirical works added human capital which is considered as another form of capital for the growth in output.

Like other countries, China's amazing economic growth also arouse the debate of whether its economy growth can be sustainable. Although numerous empirical works gave out different estimation results, most of them verified that the role of TFP is not significant in the pre-reform period, but it improved and generally became a important source of growth in the post-1978 period. The initial years of reform period, TFP improvement is attributed by agriculture institution reform. Later, it is largely from the assimilation of foreign advanced technology and reallocation of industries.

3.2 Measurement of Productivity

3.2.1 Neoclassical Growth Model

The Exogenous growth model, also known as the Neoclassical growth model or Solow-Swan growth model, was an extension to the Harrod-Domar model that included a new term, productivity growth. The most contribution was works done by Solow (1957) and Swan (1956), who developed a relatively simple growth model. Solow model extended the Harrod-Domar model by including labor as a factor of production and introducing technology as a third determinant to economic growth. The long-run rate of growth is exogenously determined. A common prediction of these model is that an economy will always converges towards a steady state of growth, which depends only on the rate of technological progress. But short-run growth can result form either technological progress or capital accumulation.

When the economy on the steady state, the sustainable growth is depended on technological progress. There are mainly three kinds of technology, namely, *Hicks-neutral* technology, *Harrod-neutral* technology and *Solow-neutral* technology.

Assuming A is knowledge. If A and L enter multiplicatively, AL is referred to as effective labor, and technological progress that enters in this fashion is known as *Labor-augmenting* or *Harrod-neutral*: $Y = F(K(t), A(t)L(t))$

If knowledge enters in the form $Y = F(A(t)K(t), L(t))$, technological progress is *Solow-neutral* or *Capital-augmenting*. If it enters in the form $Y = A(t)F(K(t), L(t))$, technological progress is *Hicks-neutral*, which implies that the technology does not affect the factor inputs ont the balanced growth path. The technological progress can offset the diminishing returns of capital so that sustainable growth happens.

3.2.2 Growth Accounting

The sustained growth in Solow model only in the presence of technological progress. With technological progress, improvement in technology continually offset the diminishing returns to capital accumulation. Solow (1957) proposed a simple accounting exercise to break down growth in output into growth in capital, growth in labor, and growth in technological growth.

Consider the production function $Y(t) = A(t)F(K(t), L(t))$, where A is a Hicks-neutral productivity term. Differentiating by t on both sides using chain rule,

$$\dot{Y(t)} = \frac{\partial Y(t)}{\partial A(t)}\dot{A(t)} + \frac{\partial Y(t)}{\partial K(t)}\dot{K(t)} + \frac{\partial Y(t)}{\partial L(t)}\dot{L(t)} \tag{3.1}$$

$$\frac{\dot{Y(t)}}{Y(t)} = \alpha_k(t)\frac{\dot{K(t)}}{K(t)} + \alpha_L(t)\frac{\dot{L(t)}}{L(t)} + R(t). \tag{3.2}$$

Here α_k is the elasticity of output with respect to capital at time t and α_l is the

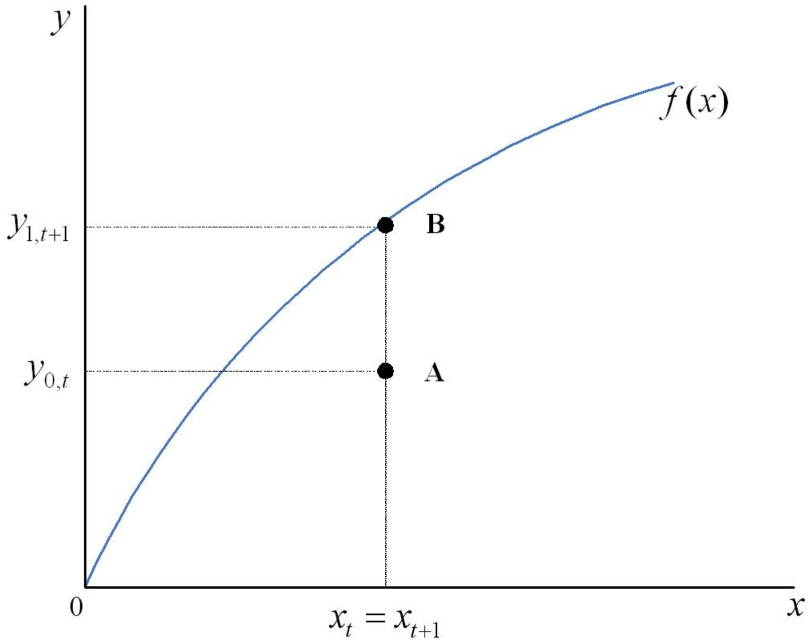

Figure 3.1: Contribution of Increased Efficiency to Productivity Growth

again the elasticity of output with respect to labor. R_t is commonly referred to as *total factor productivity* (TFP).

3.2.3 Decomposition of Productivity

It should be noticed that not only technological improvement would cause productivity to increase, but allocation of input or efficiency improvement also conduce to enhance productivity level. For instance, a educated worker is more efficient than the worker without normal training and education. Although the impacts of human capital on economic growth are controversial, we have to admitted that accumulation of human capital can lead to the increase in current technology.

Figure 3.1 illustrates an increase in total factor productivity, with no change in technology between period t and t+1 . x denotes the inputs vector while y are the output. t is time. Point A is regarded as technically inefficient because firm operated at this point below production frontier. An increase in output from $y_{0,t}$ to $y_{1,t+1}$ results from an increase in efficiency from period t to period t+1, which have the same factor inputs. Technical efficiency for a firm producing at A is measured as the ratio of its observed output $y_{0,t}$ and maximum potential output $y_{1,t+1}$, given x_t. Thus, a measure of technical efficiency can be expressed as $y_{0,t}/y_{1,t+1}$. Potential sources of efficiency improvement in newly emerging economies, like China, are

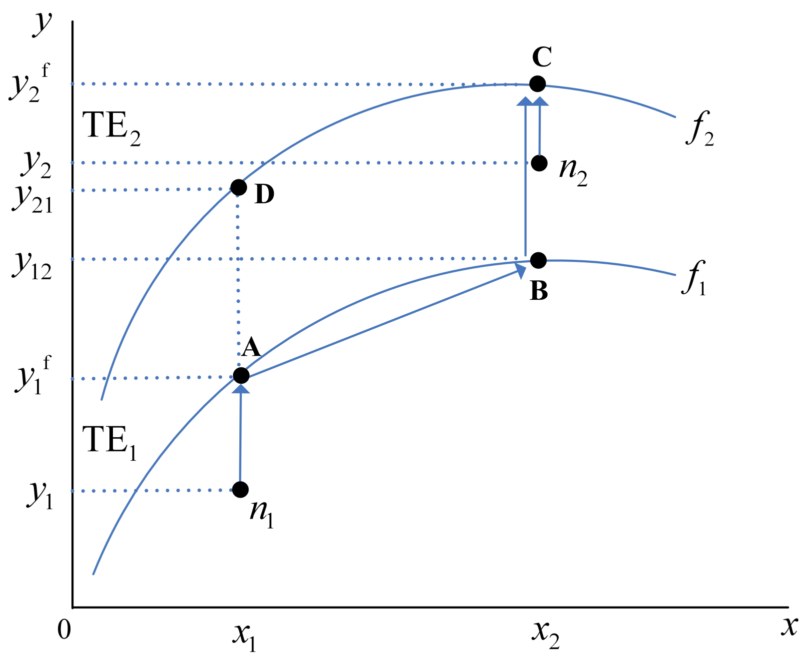

Figure 3.2: Decomposition of Productivity Change

increased international trade and competition, privatization, learning by doing, and deregulation of labor and product markets.

Productivity change could be measured and decomposed into technical efficiency (TE), technical progress (TP) and scale effect (SE). Scale effect indicated that whether a producer should increase inputs to exploit scale economies or cut back input usage if the technology exhibits decreasing return to scale (DRS) at the given level of production. The scale effect is negligible when the production exhibits CRS technology. Figure 3.2 illustrates decomposition process of productivity change from a given firm between period 1 and 2 following Kalirajan, Obwona, and Zhao (1996) and Wu (2000). In Figure 3.2, production function assumes CRS technology and TFP is decomposed into three parts: input growth, technical progress and technical efficiency improvement. In period 1 and 2, the firm faces two production frontier f_1 and f_2. For a given firm, output would be y_1^f and y_2^f with full efficient. Then firm realizes output y_1 in period 1 and y_2 in period 2. Technical inefficiency is measured by the vertical distance between frontier output y_1^f and realized output y_1 in period 1 and frontier output y_2^f and realized output y_2 in period 2, which is remarked by TE_1 and TE_2. Technical progress is measured by the distance between frontier f_1 and frontier f_2, that is $y_2^f - y_{12}$ using x_2 input or $y_{21} - y_1^f$ using x_1 input. The contribution of input growth is denoted by ΔI.

Then, referring to figure 3.2, the decomposition can be shown as follows:

$$\begin{aligned}
\Delta y &= y_2 - y_1 \\
&= (y_1^f - y_1) - (y_{21} - y_1^f) + (y_2 - y_{21}) \\
&= TE_1 + (y_{21} - y_1^f) + (y_2 - y_{21}) + (y_2^f - y_2^f) \\
&= TE_1 + (y_{21} - y_1^f) - (y_2^f - y_2) + (y_2^f - y_{21}) \\
&= TE_1 - (y_2^f - y_2) + (y_{21} - y_1^f) + (y_2^f - y_{21}) \\
&= (TE_1 - TE_2) + \Delta TP + \Delta I \qquad (3.3)
\end{aligned}$$

where $y_2 - y_1$ is output growth. In the case which is illustrated in figure 3.2, $TE_1 - TE_2 > 0$ denotes technical efficiency change and ΔTP denotes technical progress.

Since TFP defined as output growth not explained by input growth, TFP growth is the sum of technological progress and changes in technical efficiency, that is:

$$T\dot{F}P = \dot{TP} + \dot{TE} \qquad (3.4)$$

The decomposition of productivity change is important because it could provide both the valuable information about the source of productivity growth and policy implication. If a country has experience little productivity change in recent years, it can not sustain its economic growth. Thus, how to increase or keep the productivity need the result form the decomposition of productivity change. For instance, if a country has experience little technical progress, it should be better increase expenditures on research and absorb some advanced technology from developed countries. If the efficiency change perform at low level, a country should coordinate the allocation of labor and make effort to increase the education or training of its labor force. Scale effect is also informative that it tells us how to manage its input well.

Chapter 4

Econometric Approach to Productivity Analysis

Various econometric approaches can be used for the estimate of TFP such as Cobb-Douglas production function, translog production function, data envelope analysis and stochastic frontier production function. Different approaches have their advantages and limitations. To analyze the productivity performance in YRD, I think that the stochastic frontier model is more suitable for analysis. The reasons as follows:

(1) Cobb-Douglas production function assumes Constant Elasticity Substitution technology. This restrictive assumption is hard to obtain since YRD experiences the remarkable economic growth.

(2) Translog production function avoids the limitation of Cobb-Douglas production function and allows for flexible elasticities. But it can not distinguish whether the production lies on the production frontier or not. On the other hand, this model could explain the technical progress with assumption of full efficiency in each stage of production.

(3) Stochastic frontier model allows for the situation of technical inefficiency. The function form by this model can also use translog function which avoids the CES technology assumption.

4.1 Stochastic Frontier Model

From Kumbhakar and Lovell (2000), a country can be viewed as a big firm trying to maximize output using available resources. Generally speaking, the economy-wide technology may not lie on the production function. That is

$$y \leqslant f(x_n, t, \beta) \tag{4.1}$$

where y is the output level, $f(x_n, t, \beta)$ is the deterministic production frontier. x_n is the nth input. TFP is defined as the difference between aggregate output level, $\dot{y}$, and aggregate input growth $\dot{X}$. t represents technical progress.

$$T\dot{F}P = \dot{y} - \dot{X} \tag{4.2}$$

The output-oriented measure of technical efficiency is the ratio of the observed output to the best practice output, expressed as

$$TE = \frac{y}{f(x, t, \beta)}, \tag{4.3}$$

$$\ln TE = \ln y - \ln f(x, t, \beta). \tag{4.4}$$

Totally differentiating equation (4.4) with respect to t yields the following:

$$\frac{d \ln TE}{dt} = \frac{d \ln y}{dt} - \sum_{n=1}^{n} \frac{\partial \ln f(x_n, t; \beta)}{\partial \ln x_n} \frac{d \ln x_n}{dt} - \frac{\partial \ln f(x, t; \beta)}{\partial t} \tag{4.5}$$

Note that the last term on the right-hand side is technical progress (TP) and

$$\frac{\partial \ln f(x_n, t; \beta)}{\partial \ln x_n} = \frac{\partial f(x_n, t, \beta)}{\partial x_n} \cdot \frac{x_n}{y} \tag{4.6}$$

by definition. Equation (4.6) can then be rewritten as

$$T\dot{E} = \dot{y} - \sum_{n=1}^{n} \frac{\partial f(x_n, t, \beta)}{\partial x_n} \cdot \frac{x_n}{y} \cdot \dot{x_n} - T\dot{P}, \tag{4.7}$$

where $T\dot{E}$ represent the rate of change in technical efficiency and $T\dot{P}$ is the rate of technical change over time. Solving (4.7) for $\dot{y}$ yields

$$\dot{y} = T\dot{E} + T\dot{P} + \sum_{n=1}^{n} \frac{\partial f(x_n, t, \beta)}{\partial x_n} \cdot \frac{x_n}{y} \cdot \dot{x_n}. \tag{4.8}$$

The last term of this equation can be converted to

$$\sum_{n=1}^{n} \frac{\partial f(x_n, t, \beta)}{\partial x_n} \cdot \frac{x_n}{y} = \sum_{n=1}^{n} \varepsilon_n(x_n, t) \tag{4.9}$$

which is the elasticity of output with respect to the nth input. Substituting equation (4.9) into equation (4.8), we can get

$$\dot{TFP} = \dot{TE} + \dot{TP} + \sum_{n=1}^{n} \varepsilon_n(x_n, t) \cdot \dot{x_n} - \dot{X} \tag{4.10}$$

No reliable price information was available in China even after 1978. Theoretical, the aggregate input change, $\dot{X}$, is defined as the change in each of the ith input weighted by its cost share, $\frac{w_i x_i}{\sum w_i x_i}$. The absence of price information make the calculation by the contribution of change in output on the change in input impossible. Kumbhakar and Lovell (1998) use the elasticity of output with respect to each input as the weight for the change in each input. This approach is to multiply and divided by ε in the third term on the right-hand side. That is:

$$\dot{TFP} = \dot{TE} + \dot{TP} + \varepsilon \sum_{n=1}^{n} \frac{\varepsilon_i(x_i, t)}{\varepsilon} \cdot \dot{x_i} - \sum_{n=1}^{n} \frac{\varepsilon_i(x_i, t)}{\varepsilon} \cdot \dot{x_i} \tag{4.11}$$

where $\varepsilon = \sum_{i=1}^{i} \varepsilon_i$ and $\sum_{i=1}^{i} \frac{\varepsilon_i}{\varepsilon} = 1$. Grouping the last terms in equation (4.11) leads to

$$\dot{TFP} = \dot{TE} + \dot{TP} + (\varepsilon - 1) \sum_{i=1}^{i} \frac{\varepsilon_i(x_i, t)}{\varepsilon} \cdot \dot{x_i}. \tag{4.12}$$

Equation (4.12) shows that TFP change can be decomposed into technical efficiency change, technical change, and a scale effect. The rate of change in technical efficiency illustrates the rate at which a firm move toward or away from the production function. The rate of technical change, $\dot{TP}$, indicates whether the production function shifts upward, downward or remains unchanged. The scale elasticity $\varepsilon = \varepsilon(x, t; \beta) = \sum_{i=1}^{i} \varepsilon_n(x, t; \beta)$ provides a measure of returns to scale characterizing the production frontier. Under the assumption of constant returns to scale, ε would be zero and (4.12) will be:

$$\dot{TFP} = \dot{TE} + \dot{TP}. \tag{4.13}$$

If the economy is experiencing variable returns to scale, ε will be greater than one in the presence of IRS and less than one in the presence of DRS.

4.2 The Empirical Model

The stochastic frontier production function was introduced by Aigner, Lovell and Schmidt (1977) and Meesusen and van den Broeck (1977) respectively. They expanded frontier production function initiated by Farrell (1957). Here I briefly describe the stochastic production frontier for panel data since we estimate the frontier for 15 cities over a 23-year time span.

Consider a stochastic production frontier with a simple exponential specification of time-varying effects. The model is defined as:

$$y_{it} = f(x_{it}, t; \beta) \exp(v_{it} - u_{it}) \tag{4.14}$$

where $f(x_{it}, t, \beta)$ is a deterministic function of a $(N \times 1)$ vector of factor input, x_{it}, and a vector of unknown parameter, β, v_{it} are the deviations from the frontier due to the random events such as the effects of weather, luck, *etc.*, on the value of the output variable. The u_{it} are the derivations from the frontier due to technical inefficiency.

One of the simplest structures of the time - invariant inefficiency effects is

$$u_{it} = u_i \qquad i = 1, \cdots, N; \;\; t = 1, \cdots, T, \tag{4.15}$$

where u_i is treated as either a fixed parameter or a random variable - these models are known as the *fixed effects model* and *random effects model* respectively. The random effects model can be estimated using either least squares or maximum likelihood techniques. The least squares approach involves writing the model in the form of the standard error-components model discussed in the panel data literature, then applying Estimated Generalized Least Squares (EGLS). The maximum likelihood approach involves making stronger distributional assumptions concerning the u_is. For example, Pitt and Lee (1981) assumed a half-normal distribution $u_i \sim iidN^+(0, \sigma_u^2)$. Battese and Coelli (1988) considered the more general truncated normal distribution: $u_i \sim iidN^+(\mu, \sigma_u^2)$ The random errors, v_{it}, are assumed to be independently and identically distributed normal such that $N(0, \sigma_v^2)$.

The level of technical inefficiency may be influenced by different factors; my model includes several economic factors in an attempt to determine what effects that they may have on technical inefficiency. Due to the limitation of data, I just picked up some economic factors, including the number of university students in each city, whether a city locates in South Jiangsu or East Zhejiang, the economic size and land square of each city. Combining with the thorough analysis of these variables, stochastic frontier approach could help me to certify whether these economic factors could explain technical inefficiency or not.

The technical inefficiency effect involving in stochastic frontier functions was developed by Kumbhakar, Ghosh and McGuckin (1991) and Reifschneider and Stevenson (1991) in which the inefficiency effects were defined to be specific function of some firm-specific factors. Huang and Liu (1994) developed a similar model for a stochastic frontier production function in which the inefficiency effects interact with the input variables of the frontier function. Battese and Coelli (1995) proposes a model for stochastic frontier production function in panel data, in which the estimation of technical change and time-varying technical inefficiencies are allowed.

Battese and Coelli (1995) model specifies technical inefficiency effects in the stochastic frontier model that are assumed to be independently (but not identically) distributed non-negative variables. For the ith producer in the tth period, the technical inefficiency effect, is obtained by the truncation (at zero) of the normal distribution with mean $z_{it}\delta$ and variance σ_u^2, where z_{it} is a $(1 \times M)$ vector of observable explanatory variables, whose values are fixed constants; and δ is an $(M \times 1)$ vector of unknown scalar parameters to be estimated. The technical inefficiency effect, u_{it}, is specified as

$$u_{it} = z_{it}\delta + w_{it} \tag{4.16}$$

where the unexplained component of inefficiency error, w_{it}, is also distributed as the truncation of the normal distribution with zero mean and constant variance, σ_u^2. Here, w_{it} is truncated at $-z_{it}\delta$, and $w_{it} \geq -z_{it}\delta$, which is consistent with u_{it} being a non-negative truncation of the $N(z_{it}\delta, \sigma_u^2)$ distribution. Again, Battese and Corra (1977) replaced σ_v^2 and σ_u^2 by $\sigma = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/\sigma^2$.

For cross-section data, Jondrow, Lovell, Materov, and Schmidt (1982) proposed approach to estimate the mode of the conditional distribution of u_i given ε_i, which can be used as a point estimate of u_i. Battese and Coelli (1992) model specifies that the inefficiency effects are the product of an exponential function of time and non-negative firm-specific random variable, i.e., $u_{it} = \exp[-\eta(t-T)]u_i$, where η is an unknown parameter and the u_i are non-negative truncations of the $N(\mu, \sigma^2)$ distribution. However, this model does not define the inefficiency effects in terms of firm-specific explanatory variables. Battese and Coelli (1995) model assumed that the technical efficiency of production for the ith firm at t observation is defined by

$$TE_{it} = \exp(-u_{it}) = \exp(-z_{it}\delta - w_{it}) \tag{4.17}$$

To obtain estimates of TE_{it}, I firstly need to specify the function form $f(x_{it}, t, \beta)$. The common functional form used in my thesis is the translog function. The translog production function, originally developed by Christensen, Jorgenson, and Lau (1971), is widely used for estimation of production. The advantages of translog production function are such: Firstly, the translog gives a second order approximation to an arbitrary functional form and so provides for some generality. CES and Cobb-Douglas production functions are also special cases of the translog. Secondly, the translog allows for nonconstant return to scale. Finally, elasticities of substitution among inputs are allowed to vary and elasticity of scale can vary with output and input proportions.

I choose the input as capital, K and labor, L. Technological progress is captured by the time trend, t and the production function is allowed to vary over time. Thus, the translog specification of $f(x_{it}, t, \beta)$ is given by:

$$\begin{aligned} \ln f(x_{it}, t, \beta) &= \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 t + \frac{1}{2}\beta_4 (\ln K_{it})^2 + \frac{1}{2}\beta_5 (\ln L_{it})^2 \\ &+ \beta_6 \ln K_{it} \ln L_{it} + \beta_7 t \ln K_{it} + \beta_8 t \ln L_{it} + \frac{1}{2}\beta_9 t^2 + v_{it} - u_{it}. \end{aligned} \tag{4.18}$$

The method of maximum likelihood is proposed for simultaneous estimation of the parameters of the stochastic frontier and the model for the technical inefficiency effects. The likelihood function is expressed in terms of the variance parameters, $\sigma^2 \equiv \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \sigma_u^2/\sigma^2$.

Technical efficiency change, technical change and the scale effect, ε, are calculated as follows: The last term on the right-hand side in equation (4.5) is technical progress, TP. For the translog production function (4.18):

$$\Delta TP = \beta_3 + \beta_9 t + \beta_7 \ln K_{it} + \beta_8 \ln L_{it} \tag{4.19}$$

The last term in equation (4.8) are sum of the elasticities of inputs. Where ε_i is the elasticity of the ith input. The output elasticities with respect to capital and labor for the translog production function in (4.18)

$$\varepsilon_{K_{it}} = \frac{\partial \ln Y_{it}}{\partial \ln K_{it}} = \beta_1 + \beta_4 \ln K_{it} + \beta_6 \ln L_{it} + \beta_7 t \tag{4.20}$$

$$\varepsilon_{L_{it}} = \frac{\partial \ln Y_{it}}{\partial \ln L_{it}} = \beta_2 + \beta_5 \ln L_{it} + \beta_6 \ln K_{it} + \beta_8 t \tag{4.21}$$

The sum of elasticities, ε, is

$$\begin{aligned}\varepsilon &= \sum_{i=1}^{i}(x_i, t) \\ &= (\beta_1 + \beta_2) + (\beta_4 + \beta_6)\ln K_{it} + (\beta_5 + \beta_6)\ln L_{it} + (\beta_7 + \beta_8)t, \qquad (4.22)\end{aligned}$$

and the scale effect in equation (4.12) can be calculated as:

$$(\varepsilon - 1)\sum_{i=1}^{i}\frac{\varepsilon_i(x_i, t)}{\varepsilon}\cdot \dot{x}_i. \qquad (4.23)$$

where $i = K, L$ and $\dot{x}_i$ is the discrete approximation for $\dfrac{d\ln x_i}{dt}$. The technical efficiency change is that:

$$\Delta TE = \frac{d\ln TE}{dt} = \frac{TE_{t+1} - TE_t}{TE_t}. \qquad (4.24)$$

From equation (4.12) without the assumption of CRS, TFP is decomposed into technical efficiency change, technical progress and the scale effect. Thus, finally,

$$\Delta TFP = \Delta TP + \Delta TE + \Delta SE. \qquad (4.25)$$

Chapter 5

Discussion of Data

The Yangtze River Delta Economic Zone covers the area of 16 cities above prefecture level of Shanghai, Jiangsu and Zhejiang provinces. The 16 cities include Nanjing, Suzhou, Changzhou, Zhenjiang, Nantong, Yangzhou, Wuxi, Taizhou(JS), Hangzhou, Ningbo, Jiaxing, Huzhou, Shaoxing, Zhoushan, and Taizhou (ZJ). Thirty years reforms not only alter the cities of economic foundation, but also that of administration structure. The city of Taizhou in the Zhejiang province used to be called "Taizhou District", which combined some county-level cities and towns. Taizhou city was officially established in 1994 and participated in Yangtze River Delta Economic Zone in 2003. My research period is from 1985 to 2007. Unlike some articles discussing the YRD, I would like to add the Taizhou to my research because I deem that the time series of Taizhou's economic statistics is integrated and available. The land square between "Taizhou district" and "City of Taizhou" do not vary too much. The remarkable variation is caused by the reason that the administration center of city moved from Haimen county-level city to Jiaojiang county-level city.

Taizhou (Jiangsu) has only independent from city of Yangzhou since 1996. The observation for later years were re-added to city of Yangzhou. [1] Therefore, the models specified in the previous chapter are applied to the panel data of 15 cities during the period 1985 to 2007.

[1] Later discussions about Yangzhou in thesis refer to two cities: City of Yangzhou and City of Taizhou

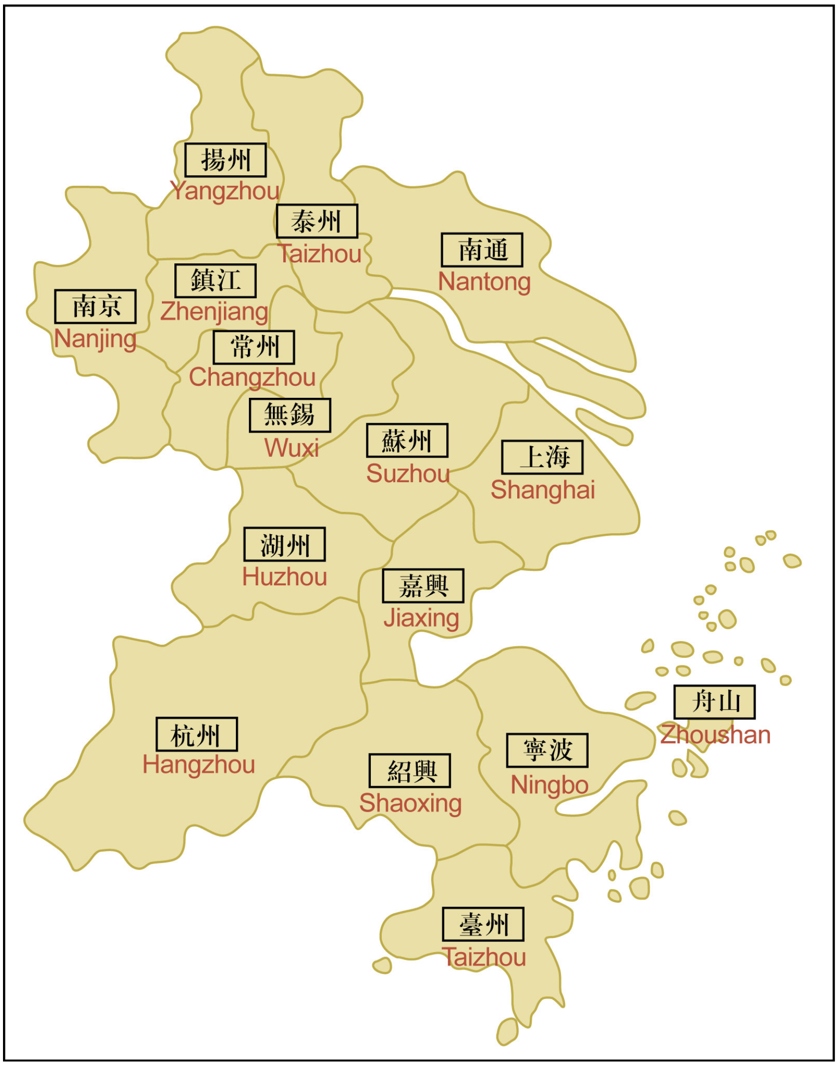

Figure 5.1: Administration region of Yangtze River Delta Metropolis Zone

5.1 Data Description

Data for each region was obtained from the relevant volumes of *Shanghai Statistical Yearbook*, *Jiangsu Statistical Yearbook* and *Zhejiang Statistical Yearbook*. Some specific data for city-level from the respective city yearbook, *China Statistical Yearbook for Regional Economy*, *Yangtze River Delta Statistical Yearbook*, *China City Development Statistical Yearbook* and *Yangtze River Delta City Development Report*. The aggregate economy-wide data is given by *Comprehensive Statistical Data and Materials on 50 Years of New China 1949-1998* and *China Statistical Yearbook 1985-2007*.

5.1.1 Output and Labor

Relevant data for each city can be obtained from the statistical yearbook in respective city. Output is measured by real GDP. As year 1985 as the basic year, nominal GDP are deflated by modified GDP deflator of each city in YRD. Labor data adopt total number of employed persons from 1985-2007 in each city statistical yearbook. [2]

5.2 Capital Measurement

5.2.1 Initial Capital Stock Estimation

One difficulty in estimating China's production function is that the statistical yearbooks do not provide data on physical capital stock. Chow (1993) derived the capital stock series for five economic sectors (i.e, agriculture, industry, construction, transportation and commerce) from 1952 to 1998 based on data of national income, fixed asset accumulation and circulating fund. The result he calculated is that total capital stock in 1952 (including land) is 175 billion yuan, while that is 103 billion yuan without land. However, this approach is not applicable for my research due to two reasons. First, data of five economic sectors in YRD is unavailable. Secondly, Chow (1993) used accumulation to substitute the measurement of investment but accumulation was no longer provided when national statistics system change in 1996.

Wu (2003) proposed a method to estimate the initial capital stock.

$$K_t = \sum_{0}^{t-1901} (1-\delta)^k \Delta K_{t-K} + (1-\delta)^{t-1900} K_{1900} \tag{5.1}$$

where K_{1900} is usually assumed to be zero when the estimation covers recent years. The advantage of this method is that it is applicable for the case of China. The assumption that the capital stock of China in 1900 is zero perfectly match the situation of China in that time. Nevertheless, this method can not be used for my research because the time series (from 1900) is too long to collect.

[2] The GDP growth deflator in Nanjing, Zhenjiang and Wuxi is unavailable in their statistical yearbooks. I have to use the GDP growth index of Jiangsu to substitute for them.

Chen (2009) estimated the initial capital stock value based on the stylized fact of growth that the capital-output ratio is constant in steady state. According to the standard Solow model, the capital-output ratio is constant in equilibrium holding an economy's saving-investment rate, growth rate of labor force and growth rate of effective labor force remain unchanged. The ratio is expressed as:

$$\frac{K_t}{Y_t} = \frac{K_{t-1}}{Y_{t-1}} = (\frac{K}{Y})^* \tag{5.2}$$

where $(\frac{K}{Y})^*$ is the steady-state value. Since $K_t = (1-\delta)K_{t-1} + I_t$, equation (5.2) becomes:

$$\frac{K_t}{Y_t} = (1-\delta)\frac{K_{t-1}}{Y_t} + \frac{I_t}{Y_t} \tag{5.3}$$

The growth equation states that $Y_t = (1+g)Y_{t-1}$

$$\frac{K_t}{Y_t} = \frac{(1-\delta)}{(1+g)}\frac{K_{t-1}}{Y_{t-1}} + \frac{I_t}{Y_t} \tag{5.4}$$

Substituting the steady state relationship from equation (5.2) into (5.4) arrives:

$$(\frac{K}{Y})^* = \frac{I_t}{Y_t}\frac{(1+g)}{(g+\delta)} \tag{5.5}$$

The method also have some shortcomings. Holding the assumption that capital-output ratio keep constant is unreasonable for the case of YRD. In my research period, real output in each city increase about 10 times and real investment increase about 4 times. From the initial period of reform, the ratio of capital-output must be above it in recent years. The assumption of constant capital-output ratio may not be warranted in YRD.

My method of estimating initial capital derived from Chou (1995) and Wu (2000). The basic physical capital estimation is by the contribution of Goldsmith(1951), perpetual inventory system:

$$K_{it} = K_{i,t-1}(1-\delta_{i,t}) + I_{i,t}$$

i defines the i city, t represents the t year, δ means depreciation. The capital stock in the initial period is assumed to be the sum of all past investment. The constant rate of capital depreciation is allowed for analysis. The investment series may be approximated by an exponential time trend:

$$I(t) = I(0)e^{\theta t} \tag{5.6}$$

Table 5.1: Lists of Rate of Depreciation

Region	Rate of Depreciation (%)
Shanghai	3.4
Jiangsu	4.2
Zhejiang	4.0

Source: Wu (2008) p.155

Using this, the capital stock in the first period is

$$K(1) = \int_{-\infty}^{1} I(t)dt \tag{5.7}$$

$$= \frac{I(0)e^{\theta}}{\theta} \tag{5.8}$$

where $I(0)$ and θ are the estimated coefficients by the regression of the constant term and TIME by linear regressions using the investment series (1985 - 2007), such that

$$\ln I(t) = C + \theta\, TIME, \tag{5.9}$$

noting that the constant term C is $\ln I(0)$.

The advantage of this method is that collected data is enough for this estimation not requiring long time-series and other unwarranted assumptions. However, since capital stock in first period is assumed as the sum of all past investment, the more long time-series, more exact the result would be. Year 1985 is a little late to assumed as first year using this approach. Thus, the estimated capital stock more or less underestimate the real level of capital, which lead to the TFP result overestimation.

5.2.2 Depreciation Rate

The depreciation rate for YRD is assumed 4%. Table (5.1) is the list of rate of depreciation for Shanghai, Jiangsu and Zhejiang by Wu (2008). Although Wu (2008) give out each provincial depreciation rate in China, he did not explicitly explain the approaches of his estimation and time series of this observation. Commonly, the depreciation rate is always assumed 5%. However, according to the finding of Wu (2008) and the possibility that the capital stock may be underestimated, I adopt 4% as the depreciation rate which is also the average rate of three regions in the table (5.1).[1]

5.2.3 Investment

The investment for each city adopt Total Investment in Fixed Assets. Although the total investment in fixed assets is not a good estimation for investment, the debate of how to estimate investment in China is always existed. Many researches use effective investment (newly increased fixed Asset) (Holz 2006) and grossed fix capital formation (GFCF)(Young 2003) to be investment.

Investment deflator can be found after 1992 using the investment price index for provinces. Before 1992, we adopt the deflator of GFCF in Shanghai to deflate all the data of YRD because the deflator of GFCF varied slightly across provinces before 1992. Zhangjun (2001) also used the deflator of GFCF as the national investment deflator.

5.2.4 Capital Estimation Result

Base on the discussion above, I calculate the initial capital stock (1985) for all cities in YRD. Table(5.2) is the lists of capital estimation result.

[1] Various depreciation rates have been used to adjust the capital consumption allowance, including 4%, 6% and 8%. Our sensitivity tests confirm that the annual growth rates of real physical capital stock are not subject to large changes to different depreciation rates used (Table 5.3).

Table 5.2: Initial Capital Stock Estimation

Region	Initial Capital Stock (Million)	% of GDP
Shanghai	3208.61	6.87
Nanjing	571.70	7.12
Suzhou	217.60	2.37
Yangzhou	137.23	1.96
Zhenjiang	127.06	4.38
Changzhou	104.75	2.33
Wuxi	196.74	2.46
Nantong	124.06	2.20
Hangzhou	338.24	4.28
Ningbo	217.52	3.35
Huzhou	48.10	2.15
Jiaxin	92.22	2.47
Zhoushan	21.41	1.63
Shaoxin	68.31	1.88
Taizhou	61.79	2.03
Total in YRD	5535.34	4.60

Source: Calculated by the author

Table 5.3: Sensitivity Analysis with Respect to Depreciation Rates: End Capital Stock Value and Annual Growth Rate

		4%		6%		8%	
	Initial Capital (Million)	End Capital (Million)	Annual Growth (%)	End Capital (Million)	Annual Growth (%)	End Capital (Million)	Annual Growth (%)
Shanghai	3208.61	6353.38	14.64	5703.47	13.89	4267.76	12.04
Nanjing	571.70	2155.82	17.00	1420.78	16.32	1095.69	14.82
Suzhou	217.60	820.91	17.01	541.04	16.32	417.26	14.83
Yangzhou	137.23	519.49	17.04	342.51	16.35	264.21	14.86
Zhenjiang	127.06	394.62	17.00	260.04	16.31	200.53	14.81
Changzhou	104.75	479.42	17.01	315.98	16.32	243.69	14.83
Wuxi	196.74	744.61	17.03	490.94	16.35	378.69	14.86
Nantong	124.06	466.59	16.98	307.41	16.30	237.03	14.80
Hangzhou	338.24	1079.15	15.61	689.62	14.88	521.46	13.16
Ningbo	217.52	698.20	15.66	446.54	14.93	337.81	13.21
Huzhou	48.10	153.58	15.61	98.15	14.88	74.22	13.16
Jiaxin	92.22	295.98	15.65	189.30	15.64	143.20	13.21
Zhoushan	21.41	68.56	15.64	43.83	15.62	33.15	13.19
Shaoxin	68.31	219.31	15.66	140.27	15.64	106.11	13.21
Taizhou	61.79	197.64	15.63	126.34	15.61	95.55	13.18

Source: Calculated by the author

Chapter 6

Empirical Analysis

6.1 Empirical Estimates

My model adopted by Battese and Colli (1995). In section 2 of chapter 4, I gave out the research models by adopting stochastic frontier approach. The parameters of my model are all calculated by FRONTIER softwares [1] and the job of adjustment of data are used by STATA and Microsoft Excel.

The estimates listed in table (6.1) indicate that all of the coefficient are significant at the 5% level, with exception of β_1 and β_2, the coefficients of $\ln(K)$ and $\ln(L)$. These coefficients however were significant at the 20% level. The signs and magnitudes for all of the coefficients are as expected. The marginal products of capital is positive meaning that the huge amount of capital have positive effect for YRD development after reform year. However, the second-order of capital is negative indicating that the capital investment will eventually diminish the output level. The marginal products of labor is positive. The second order terms are positive, indicating the increasing rate of change on labor contribution. The second-order term β_7, the coefficient of $\ln(K)t$ is positive and significant, indicating that since the marginal products of capital is positive, it has been increasing over time. The coefficient of $\ln(L)t$ is negative and significant which indicates that the marginal product of labor has been decreasing over time. This result is noteworthy in light of the fact that the dismantling of the inefficient commune system freed up a large pool of low-skilled labor which would have caused an immediate increase in output. Despite this, a majority of the labor was unskilled with

[1]More detailed operation methods or FRONTIER program could refer to Coelli (1992, 1996).

Table 6.1: Estimates of translog production function and efficiency components

Coefficient	Variable	Estimate	t-statistics	Unit Root Test	
				Levin, Lin & Chu t-statistic	Conclusion.
production function					
β_0	Intercept	2.03*	4.32		
β_1	ln(K)	0.24	1.33	-1.755	Stationary
β_2	ln(L)	0.20	0.80	-2.670	Stationary
β_3	t	0.13*	8.67		
β_4	$[\ln(K)]^2$	- 0.425*	-12.88	-3.212	Stationary
β_5	$[\ln(L)]^2$	0.40*	5.00	-2.402	Stationary
β_6	$\ln(K)*\ln(L)$	0.52*	9.81	-3.343	Stationary
β_7	$t*\ln(K)$	0.005*	2.50	-3.857	Stationary
β_8	$t*\ln(L)$	- 0.013*	-3.25	-3.212	Stationary
β_9	t^2	- 0.002*	-2.86		
Inefficiency components					
δ_0	Intercept	0.97*	6.93		
δ_1	University students	- 0.006*	-2.00	-1.987	Stationary
δ_2	South Jiangsu	- 0.21*	-7.00		
δ_3	East Zhejiang	- 0.007	-0.23		
δ_4	Size	- 0.034*	-3.40	-1.355	Stationary[1]
δ_5	Land	- 0.023*	-3.83	-5.765	Stationary
σ_u^2	Variance of inefficient	0.03*	15.00		
γ	$\sigma_u^2/(\sigma_u^2+\sigma_v^2)$	0.745*	9.68		
Adjusted-R^2			0.98		

Note: * denotes significance at 5% level.

[1] Stationary after first-differencing.

a low level of education. That, coupled with the lack of the innovation during the sample period, could explain why increases in output attributed to labor will decrease in the future. The cross-term is positive, as would expected that both inputs contribute to the growth of YRD. The coefficient on t is positive, indicating that time has contributed towards output growth. This coefficient is also proxy for technical progress, The second-order term on time is small, which means that technical progress has been decreasing very slowly. The estimate for γ, which is $\sigma_u^2/\sigma_u^2 + \sigma_v^2$, has its value of 0.745 indicating that the majority of deviation from the frontier are due to technical inefficiency. The value of γ proved again that stochastic frontier model is suitable for the analysis of YRD since it indeed existed technical inefficiency, assuming full efficient easily leading to wrong estimate of TFP.

Coefficient on UNIVERSITY STUDENTS, δ_1 is small and negative. Introduction of UNIVERSITY STUDENTS caused mean technical efficiency to decrease relative to the model without it. In modern economics, human capital is viewed as an intangible capital which affect the output growth. In my model, I just added the variable UNIVERSITY STUDENTS to test whether the university enrollment number affects technical inefficiency. YRD used to be the region with higher proportion of educated people than the rest of China. Even now, this region keep the highest density of high education schools in China. As it turns out, the coefficient on UNIVERSITY STUDENTS is negative and significant, indicating that high proportion of university students on public is beneficial to reduce overall technical inefficiency.

The second and third variables are dummy variables, SOUTH Jiangsu and EAST Zhejiang. In chapter 2, I have described the reform trace of YRD. The 30 years of reform on YRD always fills with the debates that which pattern is suitable for the case of China, South Jiangsu pattern or Wenzhou pattern. As a matter of fact, these two patterns both influenced the related cities in YRD and benefit for them to create the economic takeoff. The reason that why I added these two dummy variables is that the south JS and east ZJ have more liberal trading arrangements than the rest places in YRD. Regions in both places would engaged in a more market-style economy and would have an incentive to reduce inefficiency. Therefore, the inclusion of these variables could determine whether geographic location has any effect on the results. Finally, The results is tally with my expectation that cities which adopted the market-style development pattern in the early time reduce overall inefficiency.

The variable, SIZE, is negative and significant. If firm are not using the correct input mix, then simply increasing inputs would not necessarily reduce inefficiency. In fact, one could make the case that the size of the firm in this instance could contribute to reduce inefficiency.

The last variable, LAND, is negative and significant, which indicates that land square could affect the technical inefficiency. The land square of cities in YRD has not varied in the reform period and can be regard as constant. Nevertheless, the industry allocation in respective city has experienced the tremendous variation. The vast land which used to be farmland are converting to be used in secondary industry and tertiary industry, the process which we regard as an efficiency improvement. From table (6.3) and table (6.4), the cities with the obvious decline in the ratio of primary industry almost record the relative higher efficiency scores.

6.2 Source of Productivity Growth

6.2.1 Technical Efficiency Change

A measure of the efficiency of a firm that consists of two components: technical efficiency which reflects the ability of a firm to obtain maximal output from a given set of inputs and allocative efficiency, reflecting the ability of a firm to use the inputs in optimal proportions, given their respective prices. The economic activity is the combination of these two measures. Since reliable price information was not available, only technical efficiency change is considered here.

Table (6.3) presents the estimates of technical efficiency for each city in 1985 to 2007 as well as provides an average over time. The value of 100 indicates that there is no inefficiency and the output level of the city is on the production frontier. The average results are listed in the second column, with maximum efficiency score in Suzhou and Shanghai and minimum score in Zhoushan and Nantong. The five cities with high scores over time are Suzhou, Shanghai, Wuxi, Changzhou, Nanjing. Except for the city of Shanghai, other four cities are the typical south JS cities, indicating that the south JS pattern effectively raised the level of technical efficiency. The fourth column lists the efficiency scores in 1985. The rank of these scores is perfectly accorded with the conclusion I just addressed, the cities in south JS are on the top of rank.[2] The sixth column lists the efficiency scores in 2007. Apart from Shanghai and south JS cities, The technical efficiency in Hangzhou and Ningbo increased quickly, ranked 5^{th} and 6^{th} in 2007 while ranked 15^{th} and 14^{th} in 1985. The successful practice of Wenzhou pattern may explain

[2] In the time's view, South Jiangsu pattern appeared ahead of Wenzhou pattern.

Table 6.3: Technical efficiency estimates

City	Average efficiency	Rank based on average	Efficiency in 1985	Rank in 1985	Efficiency in 2007	Rank in 2007	Change from 1985-2007	Change of rank
Shanghai	69.97	2	47.93	2	98.75	1	50.82	5
Nanjing	60.36	5	40.21	8	96.24	3	56.03	3
Suzhou	70.63	1	46.58	3	97.76	2	51.38	4
Yangzhou	51.59	10	39.08	9	82.41	9	43.33	9
Zhenjiang	53.78	8	40.75	7	84.34	8	43.59	8
Changzhou	61.24	4	45.06	4	92.7	7	47.64	6
Wuxi	67.5	3	49.92	1	95.68	4	45.76	7
Nantong	46.71	15	37.07	13	73.71	15	36.64	13
Hangzhou	55.54	7	35.41	15	94.93	5	59.52	1
Ningbo	55.71	6	36.16	14	94.3	6	58.14	2
Huzhou	50.08	12	38.73	11	76.03	12	37.29	12
Jiaxin	51.22	11	38.28	12	79.72	11	41.44	10
Zhoushan	48.36	14	42.55	5	75.34	13	32.79	15
Shaoxin	52.9	9	40.79	6	81.09	10	40.3	11
Taizhou	49.68	13	38.87	10	75.02	14	36.15	14

Source: Compiled by the author.

the variation. In the eighth column, the change of efficiency from 1985 to 2007, Hangzhou and Ningbo are top on this rank. Of course, only these two development patterns can not fully explain the score and rank of technical efficiency. State-owner enterprises reform, FDI and education may also contribute to explain the outstanding performance of efficiency in these cities. It should be admitted that the cities with high efficiency level not only adopted the market-oriented strategy in the early time but also successfully finished the transition of simplification to diversification so that multiple factors all contribute to the growth of efficiency level.

The score of efficiency in Zhoushan, Nantong and Huzhou are always low from 1985 to 2007. I think the reason should be that reforms in these cities may have done little in the way of changing the state-owned industrial sector and agriculture sector, such that the inefficiency of these sectors has just offset the technical efficiency gains of the other sectors. For instance, from table (6.4), primary industry in the city of Zhoushan and Nantong have occupied larger proportion in their economy than any other city in YRD. In China, primary industry absorbs too much labor with less educated and inferior equipments. Certainly, labors and product resources putting into the primary industry get the relative lower efficiency. In addition, the education condition in these cities are backward. They not only lacked the large amount of educated and well trained labors, but also the enough schools or education institutions to provide high-quality training. Merely the small amount of manufacture industry can not effectively increase the efficiency score.

Technical progress change ranged from 2.66% to 4.46% in table (6.7) over the research period, with highest change found in Hangzhou and Ningbo. The least amount of technical efficiency change can be found in Zhoushan, whose economy mainly relies on fishery and tourism industry. Table (6.5) also shows that efficiency change exceeded technological progress change in whole YRD. In this sense, efficiency change has played a greater role in contributing to TFP growth than has had changes in technological progress and so TFP growth is due more to movement towards frontier than to outward shifts of the production frontier.

Two significant variations of technical efficiency should be mentioned. One happened in the period of 1988-1990, the other is the period of 1991-1992. In the first period, great changes in East European caused the domestic politics circum-

Table 6.4: The Distribution and Growth of Three Major Industries in YRD (1980 - 2003, %)

City	Primary Industry			Secondary Industry			Tertiary Industry		
	Ratio	(%)	Annual	Ratio	(%)	Annual	Ratio	(%)	Annual
	1980	2003	Growth Rate	1980	2003	Growth Rate	1980	2003	Growth Rate
China	30.1	14.6	4.7	48.5	52.5	11.3	21.4	33.2	10.3
Shanghai	3.2	1.5	2.6	75.7	50.1	9.7	21.1	48.4	11.5
Nanjing	12.3	4.1	4.2	66.3	51.0	14.6	21.4	44.8	14.5
Suzhou	24.7	2.7	3.7	58.6	63.2	15.8	16.7	34.1	16.0
Wuxi	12.3	2.8	5.0	70.5	57.5	15.3	17.2	39.7	15.7
Changzhou	21.5	5.2	4.7	62.7	57.7	14.1	15.8	37.1	14.5
Zhenjiang	24.4	5.1	7.6	60.2	57.2	15.6	15.4	37.7	14.5
Nantong	32.6	13.8	6.0	45.1	51.4	13.7	22.3	34.8	11.3
Yangzhou	39.8	10.8	4.7	43.5	51.4	15.1	16.7	37.8	13.8
Taizhou	44.4	12.5	4.1	38.5	51.8	14.6	17.1	35.7	12.4
Hangzhou	20.1	6.0	5.0	62.3	51.9	15.2	17.6	42.1	15.7
Ningbo	29.4	6.3	5.0	52.6	56.0	16.9	18.0	37.7	15.6
Jiaxin	39.1	8.0	3.9	42.5	59.3	15.4	18.4	32.7	14.2
Huzhou	40.2	11.3	4.8	40.2	53.3	16.0	19.6	35.4	13.7
Shaoxin	39.8	7.6	5.2	40.4	59.2	19.4	19.8	33.2	13.4
Zhoushan	38.9	19.2	4.6	34.9	41.3	14.5	26.2	39.6	12.0
Taizhou	43.3	9.3	5.0	34.2	58.1	20.8	22.5	32.6	15.5
YRD	16.0	5.1	4.8	64.2	54.6	13.3	19.8	40.3	13.3

Source: Compiled by the author.

Note: Territory Industry: Banking and financial services, logistics, tourism etc.

stance unstable. Politics crisis in 1989 seriously counteracted the original tendency of economy. Reform was forced to stagnated once a time. Thus, no matter what TFP or efficiency change both recorded the lowest score in this period. When the crisis impact generally faded, YRD attained the precious development opportunities. In 1990, Pudong exploitation started. Dengxiaoping "South Trip" in 1992 ascertained the engine position of YRD in the economy of China. After that time either TFP or efficiency change increased remarkably.

6.2.2 Technical progress

The technical progress component may include changes in tangible tools or knowledge, or it may be the portion of total factor productivity growth not accounted for by the change in technical efficiency and scale effect.

Average technological progress is 3.34% in the table (6.7). The highest level of technical progress was found in Hangzhou, Ningbo and Nanjing. The lowest level of technical progress was found in Zhoushan, Taizhou and Wuxi. In the past, Hangzhou and Nanjing, the capitals of ZJ and JS provinces, are important heavy industry cities in China. Before the economic reform, the economy of these cities are largely depended on large-scale SOEs or secondary industry, which provided them a superior basis for the later development. Besides the excellent prerequisite of industry, as the capitals, they were always provided the priority opportunity. Large amount of high education institutions and high technology companies make the cities as the center of technology advancement in each province. Thus, it is not surprising that these two cities get the highest scores in technical progress.

Zhoushan is a city which is well famous of its fishery and tourism industry. Lacking the infrastructure and basic education investment should be the main reasons for its low score. Wuxi seems so special because this city has the dazzling economic achievement. As matter of fact, cities in south JS all record relative rank in technical progress. Why the city in south JS recorded such low score of technical change.

Kim and Lau (1994) have proposed several possible explanations which may be applicable to the case of south JS cities. First, as the emerging engine of Chinese economy, YRD has been playing "catch - up" in technology. Most of their capital goods tend to be off-the-shelf and likely to be new capital goods to replace

Table 6.5: Average growth rates across cities

Year	TFP(%)	Technological progress	Efficiency change(%)	Scale effect
1986	8.41	7.9	0.4	0.07
1987	8.69	7.73	0.93	0.06
1988	9.14	7.57	1.47	0.1
1989	2.08	7.31	-5.25	0.03
1990	6.99	7.2	-0.28	0.07
1991	7.1	6.93	0.17	0.004
1992	14.56	6.74	7.83	-0.01
1993	13.03	6.54	6.49	-0.01
1994	11.88	6.36	5.53	-0.01
1995	11.09	6.16	4.94	-0.01
1996	9.93	6	3.94	-0.02
1997	8.79	5.83	2.99	-0.02
1998	10.55	5.7	4.9	-0.05
1999	9.64	5.55	4.16	-0.06
2000	9.81	5.36	4.53	-0.07
2001	10.36	5.21	5.25	-0.09
2002	9.62	5.02	4.68	-0.09
2003	11.34	4.8	6.63	-0.09
2004	10	4.59	5.5	-0.09
2005	8.69	4.33	4.44	-0.08
2006	8.48	4.1	4.47	-0.08
2007	7.58	3.85	3.81	-0.08
Average	9.39	6.04	3.37	-0.02

Source: Complied by author

the older ones. The current factor endowment enlarge the contribution of capital while reduce the level of technical progress. Second, although manufacture industry in YRD is prosperous and it is a main driver for the economy, relevant products are limited to traditional area like textile and handicraft, lacking innovation and technology advancement. High-technology industries and innovation products did not take up the primary position. Due to the advantage of low labor cost, traditional area is also competitive and unwilling to change. Third, the influence of omitted variables such as human capital and R&D capital. It is possible that these omitted variables are not actually important.

Also from table (6.7), the contribution of technical progress is below that of technical efficiency. Except for the reasons I addressed for low level of technical progress in some cities, the reasons partially attributed to the successful effort to increase efficiency. Although technology innovation or high technology development may spend long time, YRD officials have taken big effort to raise the education level, concentrate on training of labor and finished preliminary allocation of industries in recent years. These remarkable achievement in this area undoubtedly increase the efficiency level. The task in the future is that YRD should take its attention on technology innovation, specially self-developed high technology. With the large amount of educated people and free circumstance, a higher TP contributed could be expected in the future.

6.2.3 Scale Effect

The output elasticities for our model indicate that output is more responsive to a change in the labor input than the capital input in YRD zone. In the city-level, some cities have higher score in e_K and some cities have higher score in e_L. In Yangzhou, Nantong, Shaoxin and Taizhou, output is more responsive to a change in capital since these cities are now experiencing the phrase of capital accumulation. The increase in capital investment can effectively raise the city output level. It should be attention that these four cities are cities with largest population in YRD. The average elasticities with respect to capital and labor in whole YRD are 0.41 and 0.63 for the sample period. The sum of the elasticities is approximately 1.04, which indicates the presence of mildly increasing returns to scale. The presence of scale effects might explain why YRD has become the largest recipient of FDI. Foreign investors, recognizing the presence of scale economies, would naturally wish to exploit the opportunity by investing their capital in an area where the perceived rate of return is higher.

Some of the cities in YRD experienced decreasing return to scale. The typical representative cities are Huzhou and Zhoushan. The reason for this situation is

Table 6.6: Elasticity estimate

City	Mean e_K	Mean e_L	Mean $e_K + e_L$
Shanghai	-0.255	1.71	1.45
Nanjing	-0.14	1.32	1.18
Suzhou	0.368	0.74	1.11
Yangzhou	0.754	0.36	1.11
Zhenjiang	0.246	0.7	0.94
Changzhou	0.31	0.69	1
Wuxi	0.23	0.83	1.06
Nantong	0.76	0.34	1.09
Hangzhou	0.31	0.85	1.17
Ningbo	0.44	0.67	1.11
Huzhou	0.6	0.25	0.86
Jiaxin	0.52	0.44	0.97
Zhoushan	0.423	0.24	0.7
Shaoxin	0.78	0.18	0.97
Taizhou	0.91	0.06	0.98
YRD	0.41	0.63	1.04

Note: e_K and e_L denote elasticity of capital and labor, respectively. All results are the average number

not hard to explain. Zhoushan and Huzhou have the relative higher proportion of primary industry and population density of these cities also are very high. They need industrial reallocation and upgrade to increase the growth of efficiency and TFP. Simply putting more capital and labor would cause the negative effect on the recent situations. Shanghai has the highest labor elasticity and the lowest capital elasticity whereas Zhoushan lies at the opposite. Thus, there is a dichotomy between large and small city that the most populous cities have lowest capital elasticities but the highest labor elasticities. It must is noted that the elasticity of labor in Shanghai is surprisingly high, which is partly due to the higher education development nationalwide and especially in Shanghai, partly due to the human capital development policies since 1997.

Table 6.7: Total factor productivity (TFP) growth, technological progress, and efficiency change (1986-2007)

City	TFP rank	TFP growth(%)	Technological progress(%)	Efficiency change(%)	Scale effect(%)
Shanghai	7	9.36	3.28	6.07	0.01
Nanjing	1	10.65	3.95	6.67	0.05
Suzhou	6	9.55	3.39	5.93	0.23
Yangzhou	10	8.94	3.34	5.23	0.39
Zhenjiang	4	9.82	3.26	6.65	-0.09
Changzhou	5	9.63	3.26	6.38	-0.05
Wuxi	8	9.34	2.91	6.33	0.1
Nantong	13	8.7	3.1	5.28	0.33
Hangzhou	2	10.62	4.46	5.87	0.29
Ningbo	3	10.36	4.3	5.8	0.25
Huzhou	11	8.79	3.03	6.24	-0.48
Jiaxin	9	9.3	3.32	6.07	-0.09
Zhoushan	12	8.74	2.66	7.15	-1.64
Shaoxin	14	8.52	2.95	5.7	-0.12
Taizhou	15	8.16	2.94	5.31	-0.09
YRD		9.37	3.34	6.05	-0.02

Source: Complied by author

6.2.4 Total Factor Productivity Change

Total factor productivity is explained by changes in output that is except for input contribution and including all unexplained sources. According to table (6.5), overall total factor productivity change in YRD is 9.37%. This is rather high as compared to other studies that have been done in China and the other East Asian countries. Borensztein and Ostry (1996) indicated that TFP growth in China was 3.8% during 1979 - 1994, while Wu (1997) claims that for the period 1982 - 1995 it was about 5%.It should be noticed that the growth rate of TFP in YRD has declining recent years, which indicates that the contribution of productivity are shrinking. To sustain the high rate of growth, YRD should take the effort to increase its productivity level.

In table (6.7), The highest TFP growth in Nanjing, Hangzhou and Ningbo. Taizhou and Shaoxin recorded the lowest growth rate. From city-level analysis, efficiency change contributes to most of TFP growth. Nevertheless, the variation of TFP over time is mainly caused by the difference of technological progress among all cities. The cities which have low technology progress record low TFP growth.

Chapter 7

Conclusion

7.1 Summary

The 1978 reform made China successfully started the transfer from centrally-planned economy to a more market-oriented one. As the emerging powerhouse, YRD successfully raised the economic power and created splendid development achievement. YRD, as a regional metropolis zone, was established after the 1990s including 16 component cities and contributes to nearly one quarter of national GDP. Nowadays, YRD has become the biggest region of manufacture and export industries in China. The reallocation of labor and the boom of private sector with higher productivity, coupled with a high rate of capital accumulation, has beneficial for YRD to realize a tremendous rate of economic growth. In the reform history of YRD, there existed a debate about two different development strategies: South Jiangsu pattern and Wenzhou pattern. Either pattern was a precious attempt with reform encouragement in that times and proved finally as successful strategies. My research also proved that cities marked by South Jiangsu pattern or Wenzhou pattern have the higher economic efficiency and development potential than the rest of the cities in YRD.

In the first chapter, I proposed the debates about productivity in east Asia. For YRD, it also exist some doubts that whether the tremendous change in YRD just caused by capital accumulation which is similar with the case of east Asia. However, after analyzing the YRD, I definitely overthrow this doubt because productivity contribution for YRD was approaching 10%. It is rather high growth rate while compared with other emerging economies.

For model choices, I use stochastic frontier model to decompose TFP into technical progress, efficiency change and the scale effect. Besides the output and input data, some explanatory variables are added as the proxy for technical inefficiency. The model including these variables are proposed by Battese and Colli (1995). As a result, the variables : University Students, South Jiangsu, East Zhejiang, Size and Land, associated with reducing inefficiency. The parameters of these variables are all negative indicating that these components all beneficial for decreasing the inefficient level.

Panel data of 1985-2007 are analyze by translog production function causing by its more flexible assumption of constraints. The TFP are decomposed into three parts: technical progress, technical efficiency and the scale effect by stochastic frontier approach. Since YRD recorded a amazing rate of economic growth, what is the source of growth? From my analysis, YRD recorded average 9.3% TFP growth across the research period. It should be noted that 9.3% annual growth rate is pretty high. Certainly, TFP performance in each component city varied due to different development traces. Some cities which have so-called "backward advantage", like Nanjing and Nantong, have almost 10% TFP growth each year while cities which are depending on simplex industries or have larger proportion of primary industry just recording about 8% annual growth rate.

Regardless of which part of TFP describe, the regions exhibiting the highest or lowest score seem to come from the same areas. Technology progress and technology efficiency change increase always happened if one goes from less-developed cities, like Zhoushan, to relative developed cities, like Hangzhou or Nanjing. Accordingly, TFP change follows the same pattern. The number of SOEs in big cities has been shrinking, which would explain why technical efficiency change has been rapid for this big cities. The scale effect vary among cities so that the developed cities exhibit a slightly increasing return to scale while some less-developed cities exhibit decreasing return to scale.

Among the three component of productivity change, technical efficiency change is found to have contributed significantly to TFP growth of the individual cities, while technical progress and the scale effect appear to be less influential. For the whole YRD, technical efficiency has steadily increased during the sample period suggesting that reallocation of labor and industries contribute to the economic growth significantly. Technical progress have slightly decreased because although YRD growth was accomplished by substantial investment of capital, most of investment just putted into low-technology industries and provide less help for technology innovation. Manufacture industry in YRD largely focus on low-technology tradition areas, like processing and textile industry. High technology industry did not experience the rapid growth after reform period and thus can not taken up the primary position.

Although the results of my thesis provide preliminary preparation on productivity performance in YRD regional economies, future research could use another prospective to analyze this problem. The set of variable included in the inefficiency model is somewhat limited and can not be expected to completely explain all the sources of inefficiency. If someone find another way to collect more exact data, the results of estimate will be more meaningful.

7.2 Limitation and Future Research

Undeniably, the result of TFP growth in my research seems little higher. Since the research concerning TFP performance in YRD are rare, we only examines some research about China. Borensztein and Ostry (1996) indicated that TFP growth in China was 3.8% during 1979-1994, while Wu (1997) claims that for the period 1982-1995 it was about 5%. Wu (2008) details that period of 1993-1997, TFP is 1.64%, period of 1998-2000, TFP is 4.3% and period of 2001-2004, TFP is 3.56%. How to explain the average growth rate of 9% in YRD from 1985-2007?

(1). The quality of the data set can be improved once more detailed information becomes available. Constructing a more accurate measure of the capital stock will provide a better measure of the growth rate of capital and in turn, TFP growth. The initial capital stock is calculated by the sum of all the investment. Thus, the precondition is that the capital stock before research period was assumed zero which certainly do not applicable to the case of YRD. The data of capital is more or less underestimated which cause a higher TFP growth rate.

(2). labor reallocation from rural sector into other sectors has already brought labor's share in agriculture down from 71% in 1978 to 54% in 1994. (Wu 2008). If we include estimates of the "floating population", the number of labor force should increase. Unlike a country which has the boundary to control the float of population and trade, region can not count the accurate data of labor. YRD growth attracted vast number of "floating population" annually who do not have "Hukou" [1] so that it is difficult to count. I deem that the data of employed persons in my research are underestimated. After all, output should produce by the official number of employed persons coupling with "floating population" without "Hukou". Thus, since the expectation of underestimate of labor contribution, overestimate of TFP can not be avoided.

(3). Although YRD development lagged behind SEZs, most of the economic indexes in YRD are absolutely above the national average level. The average growth rate of 9% in YRD did not conflict the conclusion of nation estimation, for example 5% estimation. More liberal trade, institution innovation and larger proportion of educated labor should follow with higher estimate of TFP growth. Chen (2006) showed by DEA approach that Eastern China recorded 6.5% while the whole nation is only 3.9% during 1992-1999. The economic performance of YRD is should above that in Eastern China. Thus, 9% growth rate is also a reasonable estimate.

(4). Although 23 years is a sufficient time to discuss the past performance of YRD economy, it is not able to determine whether they could sustain the high rate of growth. The slightly decline of technical progress hint that this high rate of TFP growth can not sustain too long if we persistently ignore the introduce of technology innovation and modification of industry structure.

[1] "Hukou" is a kind of residence registration certificate in some communist countries, like China.

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Appendix A

Likelihood Function

The result of this section were originally derived by Battese and Coelli (1993) and S.C. Sharma *et al.* (2007).

The stochastic frontier model is assumed as:

$$\ln Y_{it} = \ln f(x_{it}, t, \beta) + v_{it} - u_{it} \tag{A.1}$$

where $i = 1, 2, \cdots, m$ and $t = 1, 2, \cdots, T$. Let $y_{it} = \ln Y_{it}$ so that y_{it} is the logarithm of output for the ith region in the tth time period. The density of u_{it} and v_{it} are:

$$d_1(v) = \frac{1}{\sigma_v\sqrt{2\pi}} \exp(-\frac{v^2}{2\sigma_v^2}), \quad -\infty < v < \infty \tag{A.2}$$

$$d_2(u) = \frac{1}{\sigma_u\sqrt{2\pi}\ \Phi(\delta z/\sigma_u)} \exp(-\frac{(u-\delta z)^2}{2\sigma_u^2}), \quad u \geq 0 \tag{A.3}$$

where $\Phi(\cdot)$ represents the distribution function for the standard normal random variable and the subscripts, i and t, are omitted for convenience. The joint density of u and $\varepsilon = v - u$ is:

$$d(\varepsilon, u) = \frac{\exp -(1/2)(((\varepsilon + u)^2/(\sigma_v^2)) + ((u-\delta z)^2)/(\sigma_u^2))}{2\pi\sigma_u\sigma_v\Phi(\delta z/\sigma_u)}, \quad u \geq 0 \tag{A.4}$$

Simplifying (A.4), we obtain:

$$d(\varepsilon, u) = \frac{\exp -(1/2)(((u-\mu_\star)^2/(\sigma_\star^2)) + ((\varepsilon + \delta z)^2)/(\sigma_u^2 + \sigma_v^2))}{2\pi\sigma_u\sigma_v\Phi(\delta z/\sigma_u)}, \quad u \geq 0 \tag{A.5}$$

where:

$$\mu_\star = \frac{-\sigma_u^2\varepsilon + \delta z\sigma_v^2}{\sigma_u^2 + \sigma_v^2} \qquad \sigma_\star^2 = \frac{\sigma_u^2\sigma_v^2}{\sigma_u^2 + \sigma_v^2} \tag{A.6}$$

From (A.5), the density function of $\varepsilon = v - u$ is given by:

$$\begin{aligned} d_1(\varepsilon) &= \int_0^\infty h(\varepsilon, u)du = \frac{\exp\{(-(1/2)[\varepsilon^2/\sigma_v^2 + (\delta z/\sigma_u)^2 - (\mu_\star/\sigma_\star)^2]\}}{\sigma_u\sigma_v\sqrt{2\pi}\ \Phi(\delta z/\sigma_u)} \\ &\times \int_0^\infty \frac{\exp(-1/2)[(u-\mu_\star)^2/\sigma_\star^2]}{\sqrt{2\pi}} du, \quad u \geq 0 \end{aligned} \tag{A.7}$$

After simplifying, we obtain:

$$d_1(\varepsilon) = \frac{\exp -(1/2)((\varepsilon+\sigma z)^2/(2(\sigma_v^2+\sigma_u^2)))}{\sqrt{2\pi}(\sigma_v^2+\sigma_u^2)^{-1/2}[\Phi(\delta z/\sigma_u)/\Phi(\mu_\star/\sigma_\star)]} \tag{A.8}$$

The conditional density function for u given ε:

$$f(u|\varepsilon) = \frac{\exp\{-(1/2)((u-\mu_\star)^2/\sigma_\star^2\}}{\sqrt{2\pi}\sigma_\star\Phi(\mu_\star/\sigma_\star)}, \quad u \geq 0 \tag{A.9}$$

It can be shown that the conditional expectation of $\exp(-u)$ given ε

$$TE_{it} = E(e^{-u_{it}|\varepsilon_{it}}) = \frac{\Phi[\mu_\star/\sigma_\star - \sigma_\star]}{\Phi(\mu_\star/\sigma_\star)}\exp(-\mu_\star + \frac{1}{2}\sigma_\star) \tag{A.10}$$

where we reintroduce the subscripts for clarify and so the expression in (A.6) become:

$$\mu_\star = \frac{-\sigma_u^2\varepsilon + \delta z\sigma_v^2}{\sigma_u^2+\sigma_v^2} \qquad \sigma_\star^2 = \frac{\sigma_u^2\sigma_v^2}{\sigma_u^2+\sigma_v^2} \tag{A.11}$$

Now, the density function for the output value y_{it} in (A.1) can be obtained from (A.8):

$$f(y_{it}) = \frac{\exp\{-(1/2)[y_{it} - f^\star(x_{it},t,\beta) + \delta z_{it}]^2/(\sigma_v^2+\sigma_u^2)\}}{\sqrt{2\pi}(\sigma_v^2+\sigma_u^2)^{-1/2}[\Phi(\xi_{it})/\Phi(\xi_{\star it})]} \tag{A.12}$$

where $f^\star(x_{it},t,\beta)$ denotes $\ln f(x_{it},t,\beta)$ and:

$$\xi_{it} = \frac{\delta z_{it}}{\sigma_u}, \quad \xi_{\star it} = \frac{\mu_{\star it}}{\sigma_\star}, \quad and \quad \mu_{\star it} = \frac{\sigma_v^2\delta z_{it} - \sigma_u^2[y_{it} - f^\star(x_{it},t,\beta)]}{\sigma_u^2+\sigma_v^2} \tag{A.13}$$

Let $y_i = (y_{i1}, y_{i2}, \cdots y_{it})'$ be a vector of $(T\times 1)$ and $y = y = (y_1', y_2', \cdots, y_T')'$. The logarithm of the likelihood function for the sample observation, $y = (y_1', y_2', \cdots, y_T')'$, is

$$\begin{aligned} L^\star(\theta^\star;y) = & - \frac{1}{2}(\sum_{i=1}^{n} T_i)[\ln 2\pi + \ln(\sigma_u^2+\sigma_v^2)] \\ & - \frac{1}{2}\sum_{i=1}^{n}\sum_{t=1}^{t}[(y_{it} - x_{it}\beta + z_{it}\sigma)^2/(\sigma_u^2+\sigma_v^2)] \\ & - \sum_{i=1}^{n}\sum_{t=1}^{t}[\ln\Phi(\xi_{it}) - \ln\Phi(\xi_{\star it})] \end{aligned} \tag{A.14}$$

where $\theta^\star = (\beta', \sigma', \sigma_v^2, \sigma_u^2)'$.

Using the parameter estimates, $\sigma_s^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma^2/\sigma_s^2$, the logarithm of the likelihood function would be:

$$\begin{aligned} L^\star(\theta^\star;y) = & - \frac{1}{2}(\sum_{i=1}^{n} T_i)[\ln 2\pi + \ln(\sigma_s^2)] \\ & - \frac{1}{2}\sum_{i=1}^{n}\sum_{t=1}^{t}[(y_{it} - x_{it}\beta + z_{it}\sigma)^2/(\sigma_s^2)] \\ & - \sum_{i=1}^{n}\sum_{t=1}^{t}[\ln\Phi(\xi_{it}) - \ln\Phi(\xi_{\star it})] \end{aligned} \tag{A.15}$$

where $\xi_{it} = z_{it}\delta/(\gamma\sigma_s^2)^{-1/2}$, $\xi_{\star it} = \mu_{\star it}/[\gamma(1-\gamma)\sigma_s^2]^{1/2}$, $\mu_{\star it} = (1-\gamma)$, and $\theta = (\beta', \delta', \sigma_s^2, \gamma)'$.

The partial derivation of the logarithm of the likelihood function with respect to the parameter, $\beta, \delta, \sigma_s^2$ and γ, are given by

$$\frac{\partial L^\star}{\partial \beta} = \sum_{i=1}^{n}\sum_{t=1}^{t}[\frac{y_{it} - x_{it}\beta + z_{it}\delta}{\sigma_s^2} + \frac{\phi(\xi_{\star it})}{\Phi(\star it)}\frac{\gamma}{\sigma_\star}]x'_{it} \tag{A.16}$$

where $\phi(.)$ represents the density function for the standard normal random variables:

$$\begin{aligned}
\frac{\partial L^\star}{\partial \delta} &= -\sum_{i=1}^{n}\sum_{t=1}^{t}\{\frac{y_{it} - x_{it}\beta + z_{it}\delta}{\sigma_s^2} + [\frac{\phi(\xi_{it})}{\Phi(\xi_{it})} \cdot \frac{1}{(\gamma\sigma_s^2)^{1/2}} \\
&- \frac{\phi(\xi_{\star it})}{\Phi(\xi_{\star it})} \cdot \frac{(1-\gamma)}{\sigma_\star}]\}z'_{it} && \text{(A.17)} \\
\frac{\partial L^\star}{\partial \sigma_s^2} &= -\frac{1}{2}(\frac{1}{\sigma_s^2})\{\sum_{i=1}^{n} T_i - \sum_{i=1}^{n}\sum_{t=1}^{t}[\frac{\phi(\xi_{it})}{\Phi(\xi_{it})}\xi_{it} - \frac{\phi(\xi_{\star it})}{\Phi(\xi_{it})}\xi_{\star it}] \\
&- \sum_{i=1}^{n}\sum_{t=1}^{t}\frac{y_{it} - x_{it}\beta + z_{it}\delta}{\sigma_s^2}\} && \text{(A.18)} \\
\frac{\partial L^\star}{\partial \gamma} &= \sum_{i=1}^{n}\sum_{t=1}^{t}\{\frac{\phi(\xi_{it})}{\Phi(\xi_{it})} \cdot \frac{\xi_{it}}{2\gamma} + \frac{\phi(\xi_{\star it})}{\Phi(\xi_{it})}[\frac{y_{it} - x_{it}\beta + z_{it}\delta}{\sigma_\star} + \frac{\xi_{\star it}(1-2\gamma)}{2\gamma(1-\gamma)\sigma_\star^2}]\} && \text{(A.19)}
\end{aligned}$$

Appendix B

STATA Program

B.1 Stochastic Frontier Model

generate float $\ln k \ln l = \ln k * \ln l$

generate float $\ln lt = \ln l * t$

generate float $tt = t * t$

xtset id year

generate float c0 = 2.03

generate float c1 = -0.24

generate float c2 = 0.19

generate float c3 = 0.13

generate float c4 = -0.425

generate float c5 = -0.4

generate float c6 = 0.52

generate float c7 = 0.005

generate float c8 = -0.013

generate float c9 = -0.002

generate float dk = 0.046

generate float dl = 0.007

xtset id year

generate float $ek = c1 + c4 * \ln k + c6 * \ln l + c7 * t$

generate float $el = c2 + c5 * \ln l + c6 * \ln k + c8 * t$

generate float $tc = c3 + c9 * t + c7 * \ln k + c8 * \ln l$

generate float $e = ek + el$

generate float $se = (e - 1) * ek/e * dk + (e - 1) * el/e * dl$

generate float $tfp = tc + te + se$

list tc

mean tc

list tfp

mean tfp