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PRODUCTIVITY, EFFICIENCY AND REFORM IN CHINA'S ECONOMY

Edited by
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Preface

This volume includes papers selected from an international conference organized by China's Reform and Development Programme of the Hong Kong Institute of Asia-Pacific Studies, The Chinese University of Hong Kong, the Department of Economics, University of Pittsburgh and the Institute of Quantitative and Technical Economics, Chinese Academy of Social Sciences, the People's Republic of China, which was held at The Chinese University in 3-6 August, 1992.

The conference was attended by scholars from the United States, Australia, Taiwan, the PRC and Hong Kong. In addition to Profs. Li Jingwen and Thomas G. Rawski, Prof. Mun Kin-chok, Drs. Victor Mok and Liu Pak-wai of The Chinese University, Prof. Fan Yiu-kwan of the Hong Kong Baptist University served as chairmen of conference sessions. Drs. Choi Hak, Fung Ka-yiu, Lei Kai-cheong, Sung Yun-wing and Richard Y. C. Wong of The Chinese University (who is now associated with the University of Hong Kong), Drs. Joseph Y. Lin, Francis T. Lui and Zhu Li-jing of The Hong Kong University of Science and Technology, and Drs. Chan Hing-lin and Tong Shiu-pui of the Hong Kong Baptist University served as discussants.

We would like to take this opportunity to acknowledge our deepest gratitude to the Mainline Research Scheme of The Chinese University and the Henry Luce Foundation for financial support, making possible the collaborative research project and the conference.

Kai-yuen Tsui
Tien-tung Hsueh
Thomas G. Rawski
March 1995

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Reforming China's Industrial Sector
Mapping the Transition

Gary H. Jefferson

I. Introduction

In the late 1970s, China embarked upon a historic transformation of its economy. Both casual observation and regularly published aggregate and sectoral data offer vivid evidence that China's economic reforms have greatly expanded the volume, variety, efficiency and quality of production that make for the country's rapidly growing GNP. These changes have arisen in part from changes in the structure, conduct and performance of China's state-owned industrial enterprises, both obvious and not-so-obvious.

Within the context of a major push for economic reform, change in the structure of incentives and markets within which enterprises operate can be assumed to give rise to changes in enterprise conduct. Change in the conduct of workers and managers, in turn, gives rise to changes in enterprise performance. This paradigm in which Structure affects Conduct affects Performance provides the analytical framework for this chapter.[1] The purpose of the chapter is to identify key measures of change along the dimensions of structure, conduct and performance against which to evaluate the progress of China's state-owned industrial enterprises as they make the transition from centrally planned production units to autonomous, profit-seeking, market-regulated firms.

Neoclassical economic theory yields various predictions with respect to the way in which the profit-maximizing firm can be expected to behave within a competitive market environment. We use the neoclassical framework to generate a set of predictions or measures regarding the behaviour and performance of China's state-owned enterprises during the economic transition. As sets of enterprise panel data become increasingly available, researchers are able to test, at various intervals, the extent to which Chinese enterprises conform to these predictions.

The typical Chinese enterprise does not conform to the canonical model of the neoclassical firm. China's state-owned enterprises are complex organizational forms involving various configurations of decision-making authority among supervisory agencies, enterprise managers, and workers which hold differing objectives. Outside the enterprise, markets are highly segmented and incomplete. Nonetheless, as new incentive structures are introduced into state enterprises and markets begin to emerge, we can expect that *relative* to the pre-reform period, enterprises will increasingly exhibit neoclassical-like behaviour. We should, for example, observe enterprises in transition demonstrating some responsiveness to changes in factor prices. The stronger the profit-seeking orientation of the firm, the more likely the firm is to minimize costs by adjusting its factor inputs to changing factor prices. This chapter identifies a set of similar propositions concerning changes in enterprise behaviour and performance pursuant to changes in incentives and markets.

II. Economic Performance

Before investigating change in the structure and conduct of China's state-owned industrial enterprises, we examine the evidence concerning changes in the performance of these enterprises.

Since performance represents the end of the chain of causality in the Structure-Conduct-Performance paradigm, it seems appropriate to determine first whether there is evidence of either gains or deterioration in enterprise performance. To the extent that there is such evidence, this stylized fact of changing enterprise performance begs explanation. Against this background, we examine the contribution of specific changes in structure and conduct.

Relative to an economy dominated by centrally-mandated directives and allocations, an economy where profit incentives and market competition play a significant role should reveal less inefficiency and higher rates of productivity growth. Increases in overall productivity growth should be reflected in changes at the microeconomic level, including gains in allocative efficiency, reductions in technical inefficiency, an acceleration of innovative activity or some combination of these changes. Below, we examine several propositions relating to expected performance gains in state industry.

1. *The introduction of reforms should cause overall productivity growth to accelerate relative to the pre-reform period.*

A number of studies show that productivity growth in state industry has accelerated relative to the pre-reform period. Both Chen et al. (1988) and Perkins (1988) conclude that while total factor productivity (TFP) fluctuated during the 1957-1978 period, the trend was basically flat during this period.

The most careful study of its kind with respect to its inclusion of intermediate inputs and construction of capital, material input and output price deflators is probably that of Jefferson, Rawski and Zheng (1992). They estimate that during 1980-1988, TFP within state industry grew at an annual average rate of 2.4 per cent. During the same period, TFP in the collective sector grew at an estimated annual rate of 4.6 per cent. This performance is substantially better than that recorded during the pre-reform period.

2. *More rapid sectoral productivity growth should be reflected at the microeconomic level, i.e., gains in static efficiency (i.e., gains in allocative and technical efficiency) and dynamic efficiency through an acceleration of innovative activity.*

Static Efficiency

Arbitrary price setting, the absence of factor input markets, and distorted incentives caused factor returns to be highly skewed at the beginning of the reform period. As reform introduces more uniform profit-seeking incentives and market regulation, we expect that the most extreme differences in performance to recede, causing factor returns to become more equal.[2]

Using a sample of 226 large and medium-size enterprises at the core of the state industrial system, Jefferson and Xu (1991) find substantial evidence of convergence. For labour productivity (Q/L), the (inverse of) labour's income share (Q/W), capital productivity (Q/K), material input productivity (Q/M), and nominal total factor productivity (NTFP), the results, presented in Table 1, show a monotonic convergence from 1980 to 1985 and 1989. Broken down by industry type to control for differences in technologies, this chapter shows fairly consistent patterns of convergence by industry. Most striking, however, are the patterns that are revealed when the authors hold price regimes constant. These data show that the most dramatic convergence has occurred among the enterprises that report no within-plan sales whereas the least amount of convergence has occurred among enterprises whose sales are 100 per cent within plan.

Any tendency for returns to capital to converge should also result in more equal profit rates across industrial branches within the state sector. Naughton (1992) measures changes in profit rates [(profit+tax)/total capital] across 38 industrial branches. These rates show an impressive tendency to converge as he reports that the coefficient of variation declines from 0.78 in 1980 to 0.44 in 1989.

Table 1 Coefficients of variation (CV) for factor returns: large and medium-size state-owned enterprises

Group	Year	Q/L	Q/W	Q/K	Q/M	NTFP
Full sample (226)	1980	0.91	0.86	1.04	0.29	0.32
	1985	0.85	0.80	0.82	0.26	0.26
	1989	0.76	0.73	0.64	0.25	0.21
A. Sales 100 per cent within plan (74):						
	1980		0.88	1.00	0.31	0.36
	1985		0.83	0.90	0.31	0.33
	1989		0.75	0.70	0.29	0.27
B. Sales partially within plan (105):						
	1980		0.80	1.04	0.21	0.27
	1985		0.74	0.69	0.20	0.19
	1989		0.66	0.57	0.22	0.15
C. No within-plan sales (44):						
	1980		0.83	0.80	0.27	0.22
	1985		0.51	0.61	0.21	0.14
	1989		0.45	0.49	0.22	0.12

Source: Jefferson and Xu, 1991.

Dynamic Efficiency

Based on a sample of 254 enterprises that included state-owned enterprises, urban collectives and township-village enterprises, Jefferson, Rawski and Zheng (1992), find increasing rates of innovation and increasing commitments of innovation resources to innovative activity. From 1985 to 1989, the incidence of new products as a share of total production rose within each of the three major ownership types. Within state industry, the share for all size enterprises rose from 9.2 per cent in 1985 to 19.8 per cent in 1989 for large and medium enterprises and to 37.3 per cent for small enterprises. Asked to identify the leading innovators within their product lines, a large majority of respondents of all enterprise types, over 90 per cent, identified state-owned enterprises.

III. Structure

Unlike limited economic reform which may involve discrete and independent efforts to achieve macroeconomic stabilization, or reform prices, or change regulations affecting the incentives and autonomy of the production sector, economic transition entails systemic change that simultaneously affects all aspects of the economy. In this sense, since the late 1970s, China has been involved in a full-fledged economic transition.

A priori, we anticipate that three kinds of structural changes will affect the behaviour and performance of the country's state industrial enterprises. These are: (i) reforms that strengthen managerial and worker incentives, (ii) increases in enterprise autonomy, and (iii) the emergence of a more complete and competitive market. Within each of these categories, we briefly identify key reforms that have altered the *structure* of China's industrial economy.

Managerial and Worker Incentives

1. Higher profit retention rates: Although enterprises operate under a wide variety of profit retention schemes, most enterprises operate according to a profit-contract system, in which marginal retention rates differ from — and are generally higher than — average retention rates. In the enterprise sample used by McMillan and Naughton (1992), marginal profit retention rates rose from about 11 per cent in 1980 to nearly 27 per cent in 1989.[3]

2. Increasing long-run marginal profit retention rates: During 1989-1990, the initial three-year management contracts expired, leading to the negotiation of new contracts. A key question is whether a ratchet effect occurred with these renegotiations, i.e., higher profit remittance rates were imposed on the more profitable firms. To test the ratchet hypothesis, a sample of 203 firms

was used to examine whether enterprises who, in the first period, realized profit retention rates (A) that exceeded their contracted retention rates (B) subsequently in the second period had to accept reductions in their contracted retention rates (C) relative to the retention rates specified in their original contracts. The result,

$$\text{CORR}(A/B, C/B) = 0.93,$$

yields strong evidence that refutes the ratchet hypothesis, instead suggesting that profit remittances rose proportionately less than profits.

3. Growing importance of bonuses: In the same sample, bonus payments doubled as a fraction of income, increasing from just over 10 per cent of remuneration in 1980 to almost 20 per cent in 1988, and dropping slightly in 1989 as output and profits fell under the macroeconomic stabilization programme.

Enterprise Autonomy

1. Establishment of output autonomy: During 1984-1988, most firms received output autonomy, involving the right to set total production and product mix (after satisfying an intramarginal quota). Currently, few state-owned enterprises have not received output autonomy.

2. Introduction of contract workers: State enterprises now generally hire workers on less than a permanent basis. The fraction of contract workers (generally a three-year renewable contract) rose from 1 per cent in 1980 to 15 per cent in 1989. Temporary workers, often from rural areas, are hired with increasing frequency to undertake short-term, seasonal, or cyclical work.

3. Establishment of the optimal labour combination programme: The optimal labour combination programme (*laodong youhua zuhe*), introduced in 1987, gives managers the authority to reorganize enterprises, internally reallocate workers, and reduce the workforce through early retirements, retraining assignments, and layoffs and reassignments.

Market Structure

1. Introduction of the dual track pricing system: Under the dual track system, in the sale of products or purchase of inputs at the margin, most enterprises face either market prices or negotiated prices that reflect market trends. Thus, if fixed or not subject to manipulation by the firm, at the intramargin, state prices tend to act like a lump-sum tax or subsidy. Overtime, the share of sales by state factories transacted at state prices has fallen to about 40 per cent.

2. Relaxation of the state's monopoly over industry: In 1975, over 80 per cent of China's industrial output originated with the state sector. By 1992, industrial output was nearly evenly divided between the state and non-state sectors. During the intervening period, as barriers to entry were relaxed, literally millions of new non-state enterprises entered the market, creating increasing sources of competition for the state sector. Increasing competition from the non-state sector helped to reduce quasi-rents of the state sector which fell from an average of 25.2 per cent in 1980 to 16.8 per cent in 1989 (Naughton 1992).

Taken together, these reforms represent substantial change in the internal structure and operating environment of China's state-owned industrial enterprises. Notwithstanding these reforms, industrial reform in China is very much at a "halfway house." Property rights remain ill-defined so as to create incentive distortions, government authorities continue to encroach on enterprise autonomy,[4] and rural-urban mobility and mobility between the state and non-state sectors remains limited. Still, if far from complete, China's industrial sector has been extensively reformed relative to the pre-reform period.

IV. Enterprise Conduct

Based on predictions from neoclassical theory, we anticipate that, as reforms such as those above are introduced, increasingly robust

evidence will emerge that the following behavioural conditions hold:

1. *Firms with price-setting autonomy operate on the inelastic portion of the demand curves they face.*

Since firms operating on the inelastic part of their demand curves can increase profits simply by raising prices, in a competitive neoclassical world we would not expect to observe this phenomenon. In a recent World Bank survey of 1,000 state-owned enterprises, 952 firms responded to the question: "If the price of your principal product increases to 10 per cent, by how much would you expect sales volume to fall?" About 44.2 per cent (421) reported that sales would fall by more than 10 per cent. Another 55.3 per cent (469) answered "no change" or "fall by less than 10 per cent" implying that a substantial number of firms persist in operating on the elastic portion of their demand curves.

In principle, firms operating on the inelastic portion of their demand curve are doing so due to some impediment to price flexibility — the price is government-controlled, a price increase would result in authorities raising input prices, or reducing some other benefits. As expected, nearly two-thirds (64 per cent) of the 469 respondents indicating that sales would either not change or fall by less than 10 per cent reported that government price controls were either an "important" or "very important" reason for not raising prices. When concerns about supervisory bodies responding by raising material inputs prices were included, over three-quarters (76 per cent) raised concerns about either not having the authority to adjust prices or having to pay higher prices for inputs. Still others reported concerns about the loss of other benefits in the event that they would raise prices.

Notwithstanding evidence of extensive limits to price-setting autonomy persisting, the overall picture is consistent with predictions of profit-motivated enterprise behaviour. Nearly half of the enterprises believe that they are operating on the elastic portion of their demand curves. The large majority of those that are not are able to cite a credible reason for not raising prices.

2. *Changes in relative factor prices should motivate firms to economize on that input whose relative price has risen.*

When the relative price of a factor input rises, we expect that a profit-maximizing firm will seek to economize on its use. If the firm is operating on its isoquant and substitution possibilities exist, the firm should save on the more costly input by substituting inputs that have become relatively more inexpensive. Alternatively, if slack exists due to bounded rationality or some other cost involved in eliminating the slack, an increase in the price of the under-utilized factor should motivate a reduction in its use. Thus, whether through substitution or greater efficiency, we expect that the relative increase in the price of a factor of production will result in greater economy in the use of that factor.

In their relatively small sample of 20 enterprises, Jefferson and Xu (1991) find that a rise in the share of self-financed investment is associated with increases in the profitability of investment. Apparently, the higher opportunity cost associated with self-financed investment, relative to state grants or bank loans, causes enterprises to be more selective in their financing of investment projects. These authors also find evidence in support of the proposition that enterprises with the largest outside share of material inputs enjoy the highest levels of material productivity. That is, relatively high market prices in lieu of the guarantee of state prices tend to motivate enterprises to economize on material inputs.

This is one aspect of enterprise conduct where available evidence is extremely thin. Additional investigations are needed to determine the extent to which enterprises are responsive to changes in relative factor prices and have become *increasingly* responsive to such changes.

3. *Managers will use their newly acquired powers to raise efficiency and profits.*

McMillian and Naughton (1992) ask the question: "Did managers respond to autonomy by strengthening workers' incentives?" They conclude that both bonus payments as a fraction of

remuneration and bonus payments per capita are significantly and positively associated with output autonomy and the profit retention rate. The authors also report evidence that the fraction of contract workers is significantly positively associated with output autonomy.

Like many enterprise reforms, the optimal labour combination programme is an enabling programme, it is not mandatory. By early 1992, 34,973 enterprises with a work force of 10.53 million workers had implemented the programme.[5] Interviews with factory managers indicate that, because it entails reassignments and often reductions in work force, the implementation of the optimal labour combination programme represents a difficult managerial challenge. This is one reason that it is far from universally implemented. Jefferson and Xu (1991) find that in their sample, where this programme has been implemented, it has succeeded in statistically significant gains in labour productivity.

4. *Labour should be compensated in accord with the value of its marginal product.*

One conclusion that emerges from an analysis of various industrial data sets is that during the 1980s, the wage-efficiency linkage has, as hoped by China's reformers, become considerably stronger. Based on a set of 359 industrial enterprises, the relationship between labour productivity and the total wage per worker, in both 1980 and 1987, is found to be statistically significant. While in 1980, changes in labour productivity could explain only 3.8 per cent of the variation in wages about its mean, seven years later, variation in labour productivity was able to explain 37.3 per cent of the observed variation in wages. The finding indicates that, during the 1980s, a significantly larger part of the compensation package became variable and dependent on productivity differences while the size of the fixed component declined.

As well as finding significant and increasingly strong associations between wages and labour productivity, we expect to observe increasingly strong links between bonuses and profits. One study shows that during 1986-1988, within a relatively small sample, bonuses were responsive to changes in net profits. A one *yuan* increase in net profits was typically associated with a 26 *fen* increase in the bonus and welfare fund, whereas a one *yuan* decrease in net profits occasioned only a 4 *fen* decline in the bonus and welfare fund (Jefferson and Zou 1989:24). Notwithstanding this ratchet effect, the difference in the reward to rising over falling profits appears sufficiently large to motivate increased effort.

5. *The most profitable enterprises should expand their production capacity most rapidly.*

According to Kornai, a key deficiency of the soft-budget constraint is that it eliminates any connection between enterprise performance and the propensity of enterprises to invest and expand capacity. Otherwise, if budget constraints were binding, over time, more profitable enterprises would expand their market shares and, while soft-budget constraints and public subsidies might persist for inefficient enterprises, their relative weight in the economy would decline over time.

To investigate whether the most profitable enterprises are most rapidly increasing their capacity, as would occur within an allocatively efficient economy, Jefferson and Xu (1991) examine the relationship between profitability and capacity growth using data from a sample of 110 iron and steel enterprises over the period 1985-1987. During this period, they find that the growth of net fixed assets is positively and significantly associated with profitability. Thus, at least for one key Chinese industry, we are able to observe this critical link. There still remains the question concerning the extent to which this association between growth and profitability is becoming stronger over time which will have to be resolved through the use of a longer set of panel data.

These propositions and the related evidence indicate that China's state industry is becoming increasingly disciplined by profit incentives and market regulation. This is not an exhaustive set of testable implications of an increasingly competitive industrial system, but it does indicate the possibilities for evaluating the effect of reform on enterprise behaviour within an industrial system in transition.

V. Conclusions

In his recent contribution to a report of the U.S. Congress Joint Economic Committee, James B. Stepanek (1991) gave the following title to his article on Chinese industry: "China's Enduring State Factories: Why Ten Years of Reform Have Left China's Big State Factories Unchanged." In the paper, following a survey of institutional changes in state factories, Stepanek contends:

> The amazing period of rapid change has come and gone, leaving many things intact. The reforms, for all their impact on collectives, hardly penetrated China's state-owned factories. (p. 441)

The purpose of the current chapter is to demonstrate that, for the purpose of evaluating state industrial enterprises in transition, it is not sufficient to draw conclusions from observations of institutional reform alone. Reform is a subtle process in which vast changes in performance may result from seemingly small changes in structure, or, alternatively, negligible change may ensue from apparently major reform.

In recognition of the fact that institutional change is merely the first step in a process of reform, this chapter seeks to set up a framework to evaluate the impact of structural reforms on the conduct and performance of state enterprises. Rather than drawing untested inferences from observations of institutional change, as Stepanek does, this chapter argues the importance of collecting statistical data to measure and test the significance of changes in enterprise behaviour and performance that can reasonably be predicted from the reforms. In this way, we map and test the progress of the transition enterprise.

In concluding, as we do at least tentatively, that the reform of China's state industrial enterprises has met with considerable success, we must also come to terms with widespread reports of the persistent or even deteriorating profit performance of the state sector. During 1986-1988, the losses of state industry as a share of GDP ranged from 0.5-0.6 per cent. By 1990, they had grown to nearly 2 per cent and then declined marginally in 1991 to 1.73 per cent. How can productivity be rising as argued above even as losses grow? Is there any way of reconciling this apparent contradiction between declining profitability and rising productivity?

Some of the increase in losses resulted from the decline in aggregate demand during the macroeconomic stabilization programme launched in late 1988 and continuing into 1991. During this period, growing losses and declining or at least stagnant productivity do seem to have moved together. As China's industrial economy emerges from its managed recession, losses of state industry as a share of GDP should fall.

The broader issue of the persistence of structural losses and a secular decline in profitability in state industry reflects two conditions: (i) the state policy of under-pricing below economic cost in certain industries, particularly in the extractive industries, and (ii) the erosion of the state's monopoly over industrial production and widespread entry of non-state owned industrial enterprises. Recent increases in coal and petroleum prices should be alleviating losses within the energy sector; the extent to which they create losses downstream will depend on short- and long-term supply and demand elasticities. Increasing competition from the entry of new industrial enterprises has eroded quasi-rents within both the state and non-state industry as profit rates have become more equal both between state and non-state industry and across industrial branches (Naughton 1992).

A critical dimension to China's industrial transition is the phenomenon of "growing out of the plan." At the beginning of the reforms, nearly 80 per cent of China's industrial output was produced within the plan. Now, with the share of within-plan state production having fallen to about 20 per cent and state industry itself representing just half of total industrial output, industrial output produced under the state plan now represents only about 20 per cent of China's total industrial output. As a strategy of

medium-term transition, China's "growing out of the plan" strategy has produced an effective roadmap of industrial transition.

* *The author gratefully acknowledges financial support from the Henry Luce Foundation, the Chinese Academy of Social Sciences, and the World Bank. Also appreciated are comments and suggestions of Thomas Rawski, Richard Y. C. Wong, and other participants in the "Conference on Productivity, Efficiency and Reform in China's Economy," The Chinese University of Hong Kong, 3-6 August 1992. All views and any errors in the chapter remain solely the responsibility of the author.*

Notes

1. See, for example, Bain (1959) and Sherer (1980) and an initial application to Chinese industry by Jefferson and Xu (1991).
2. This expectation assumes that the introduction of incentive reforms is widespread and is accompanied by expanding product markets and factor mobility. If, alternatively, incentive reforms are localized and sporadic and markets are segmented, it is possible that distortions in factor returns may be made more pronounced.
3. The data set includes annual data for 1980-1989 for 769 enterprises in four provinces (Sichuan, Jiangsu, Jilin, and Shanxi). All the enterprises are state owned; within the population of such enterprises, larger state-owned enterprises are somewhat over-represented.
4. See, for example, Perkins' (1993) list of eight measures that limit enterprise authority.
5. "Labour Reform Progressing 'Quite Rapidly,'" Beijing Xinhua Domestic Service, 16 March 1992, reported in *China Development News*, World Bank, 8 April 1992.

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2

Productivity and China's Economic Growth, 1953-1990

Li Jingwen
Gong Feihong
Zheng Yisheng

I. Introduction

It is common knowledge that with the exception of 1989 and 1990 the Chinese economy has grown rapidly since 1978 after implementing the reform and open-door policy. As a result, the strength of China has been greatly enhanced and the living standards have improved considerably. Many economists, both at home and abroad, have taken an interest in the economic growth of China. Some studies have been conducted to explain the sources of the economic growth of the economy.

Since the data available do not satisfy the assumptions underlying a production function approach to the study of economic growth, most researchers arrive at different conclusions depending on the data which they collect from different sources. Influential studies include: the study on the productivity of Chinese state-owned industries during the period of 1953-1983 by Tidrick

(1986), the economic specialist of the World Bank, which was finished in 1986; the collaborative research on productivity of accounting-independent firms in Chinese industries from 1953-1985 by Chen et al. (1988); the study on multi-factors of productivity and the sources of growth of the Chinese industries between 1980 to 1985 by Mcguckin et al. (1989); the research about the determinant factors of the China's economic growth (1952-1987) based on the Material Product System (MPS) by Shi et al. (1990); the technical progress and industrial structure by Li et al. (1989). In 1988, cooperation began with the research group which was led by Jorgenson from Harvard University. We had finished the research project, "Sino-American-Japanese Productivities and Economic Growth." Specialists in this conference are also very interested in Chinese economic growth research and have made many contributions to it.

In this chapter, we have studied both the long-term growth of the Chinese economy from 1953 to 1990 at the aggregate level and the short-term growth of 34 industrial sectors between 1981 to 1987 based on the System of National Accounts (SNA). Moreover, we will adopt the method proposed by Christenson et al. (1973) to China.

II. The Sources of China's Economic Growth

After the People's Republic of China was founded in 1949, it took three years for the Chinese economy to recover from the devastation of the war. The Chinese economic strength increased 11.7 times over a period of 38 years, i.e., from the beginning of the First Five-year Plan (1953) to the end of the Seventh Five-year Plan (1990). However, per-capita GNP only increased 5.88 times because of rapid population growth. On the other hand, owing to misguided policies, serious natural disasters and political disturbances, the economic development of China was unstable before the reform and open-door policy was introduced in 1978. The economy has grown more smoothly and continuously after 1978

as shown in Figure 1. Of the 26 years before 1978, there were six years in which the economy experienced negative growth. The most serious economic downturn occurred after 1959 and persisted for three consecutive years. After three years of adjustment, the economy of 1965 just approached the level attained in 1959. In addition, the output of the economy of 1969 just surpassed that of 1966 after two years' (1967, 1968) of negative growth. These two disturbances greatly hindered the economic development of China. Figure 2 shows that the annual growth rates of the Chinese economy fluctuated greatly over the 26 years before 1978. The economic development was more stable during the last 12 years, though the annual growth rates were by no means uniform each year. The growth rates of nine years were higher than the average growth rate of the previous 38 years.

As shown in Figure 3, the per-capita GNP and labour productivity of the whole society exhibited the same pattern of fluctuation as that of economic growth. During the 38 years, the population doubled and the labour force of the whole society increased by 1.74 times, so that the growth of per-capita GNP and labour productivity of the whole society were restrained. Even though, the average annual growth rate of labour productivity was 4.05 per cent from 1953 to 1990, it jumped up to 5.42 per cent after 1978.

It can also be seen from Figure 4 that the growth rate of per-capita GNP fluctuated more frequently during the first 26 years (1953-1978). A very high positive growth was often followed by a very remarkable negative growth. During this period, the average growth rate was 3.29 per cent and was 0.76 per cent less than that of the whole period of 38 years. In the next 10 years after 1978, there were nine years in which the growth rates were 0.5-6.4 per cent higher than the average of the whole period, except 1981. Affected by inflation and following recession, the growth rates in 1989 and 1990 went down. The per-capita GNP of the last 12 years increased, significantly strengthening the economy of China. After experiencing violent fluctuations in the first 26 years, the labour productivity of China grew more smoothly after 1978.

Figure 1 Growth of Chinese GNP, 1952-1990

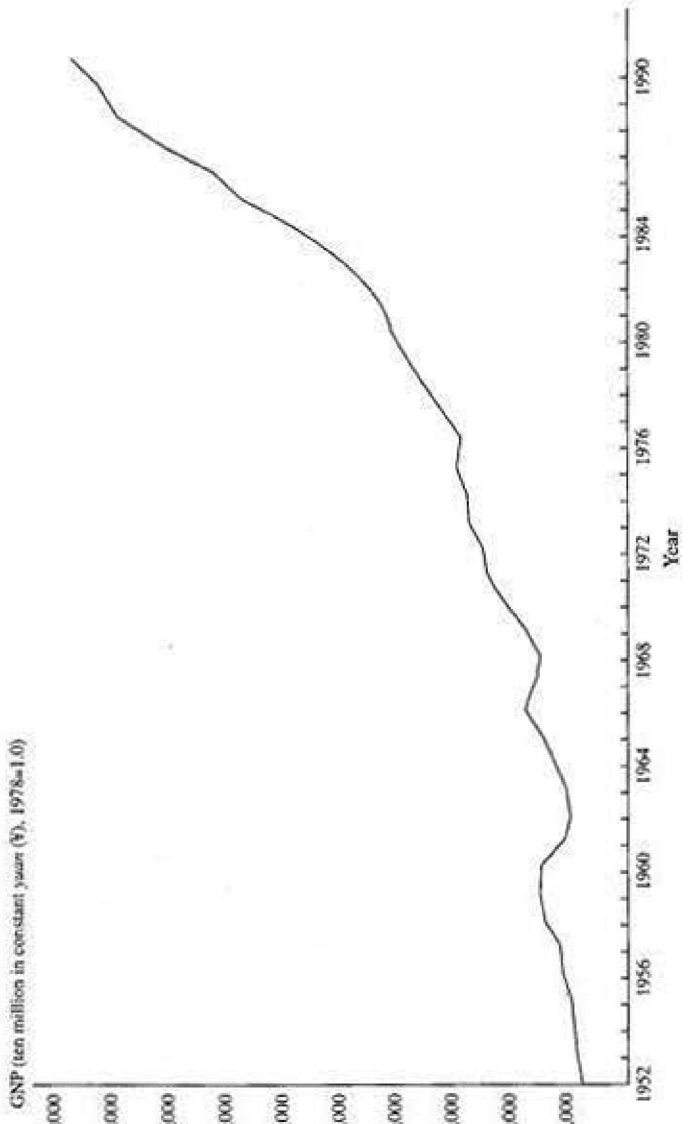


Figure 2 Growth rates of the Chinese economy, 1953-1990

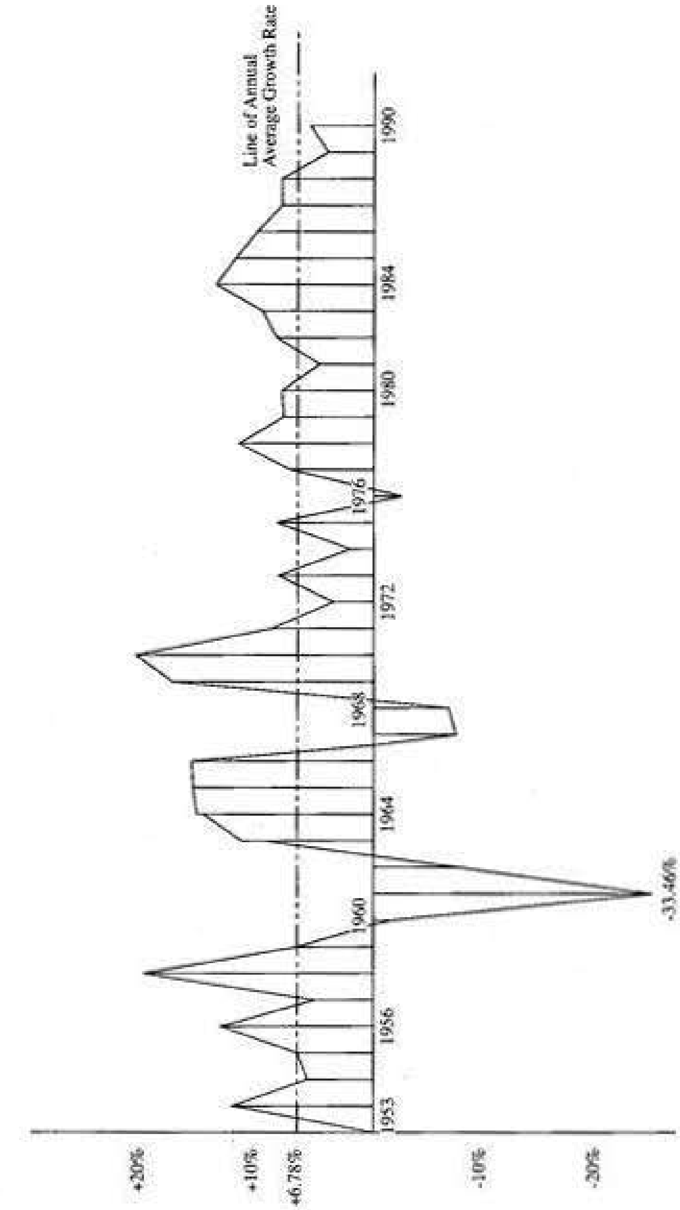


Figure 3 China's GNP per capita, social labour productivity and capital productivity (x 500), 1952-1990

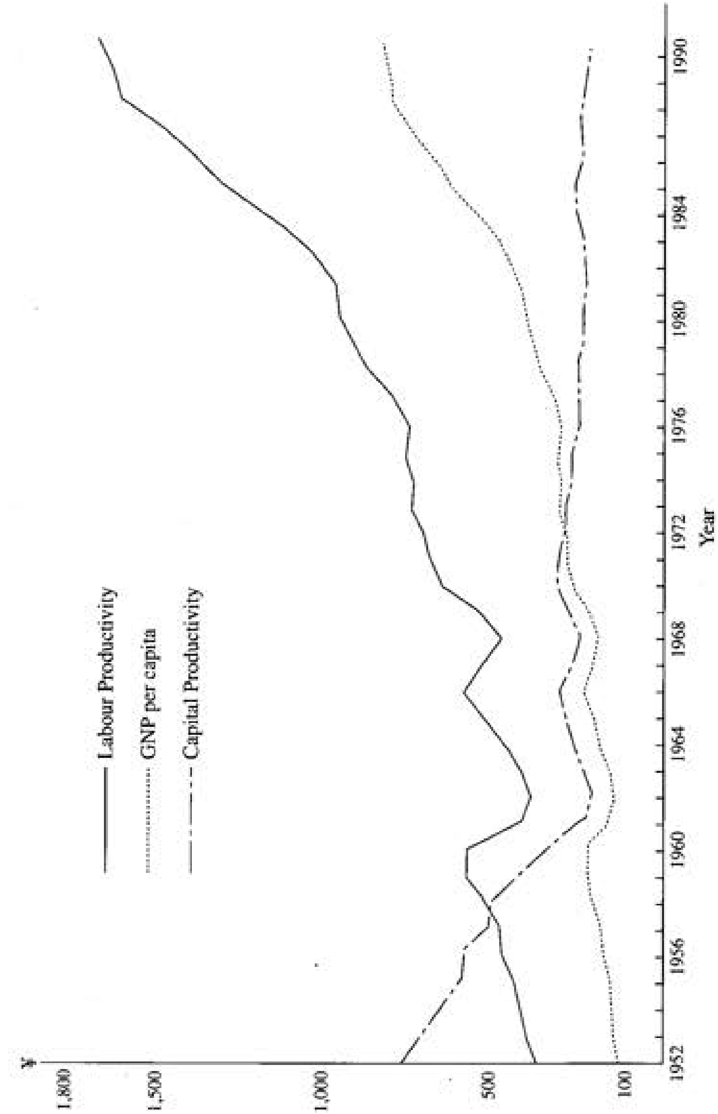
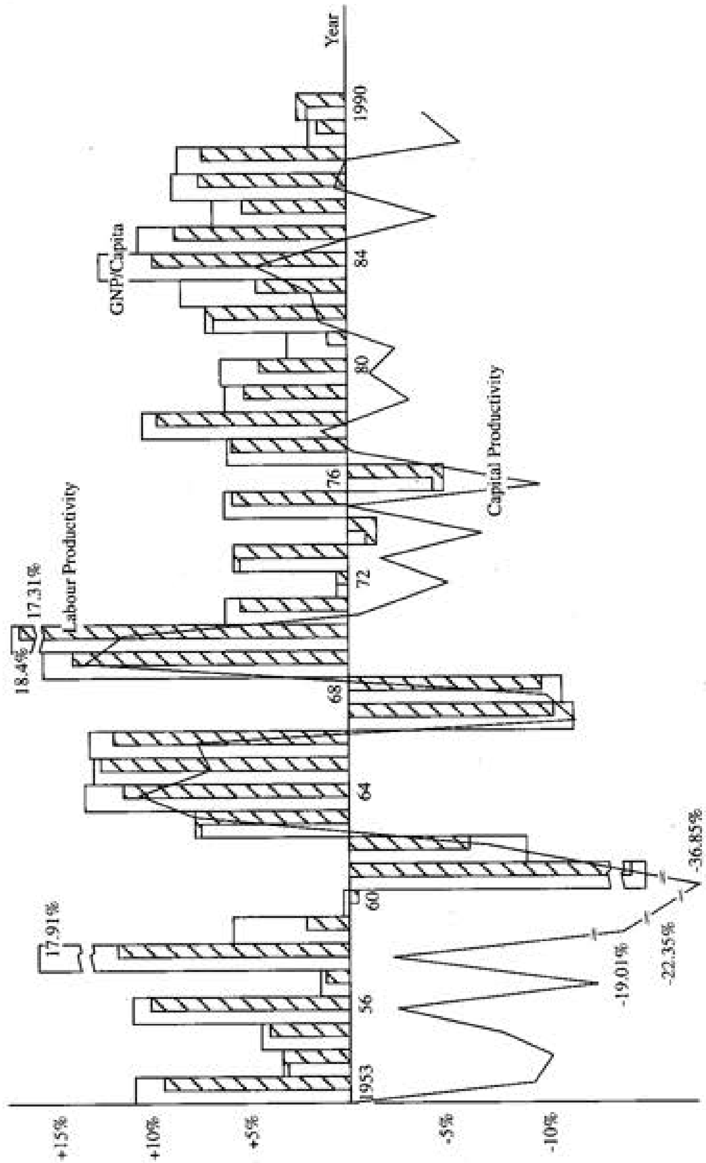


Figure 4 The annual growth rates of GNP per capita, social labour productivity and capital productivity, 1953-1990



However, it was adversely affected by the depression after the inflation of 1988. Capital productivity had experienced negative growth in 9 years out of 11 after 1967, and there were positive growth in 7 years out of the last 12 years after 1978.

In the following, we analyse the sources of growth of the Chinese economy:

(1) The result pertaining to the growth rate of output, input and productivity in the Chinese economy. For different periods, Table 1 reports the various indexes for (i) the whole period (1953-1990), (ii) the two sub-periods, one before and one after economic reform, and (iii) all the periods corresponding to the Five-year Plans at the aggregate level with the exception of the second and third one (for there were negative increases in the 10 years of these two Five-year Plans).

The second column of Table 1 presents figures for the period from 1953 to 1978 preceding the reform and open-door policy; the third column is the period from 1979 to 1990; the remaining columns report figures corresponding to the Fifth, Sixth, and Seventh Five-year Plans. The average rate of economic growth was 6.78 per cent for the whole period. At the same time, the average growth rate of labour was 2.73 per cent. The share of contribution of capital input to economic growth was 75.07 per cent, and the share of labour was 19.47 per cent. The contribution of both capital and labour inputs accounted for 94.54 per cent of growth. The proportion of contribution of productivity to the economic growth was only 5.46 per cent.

During the 26 years before the reform period, the contribution of productivity to economic growth was negative. After the reform, the average rate of economic growth was 8.35 per cent in the last 12 years, and the average growth rate of capital stock and that of labour were 9.15 per cent and 2.93 per cent respectively. The shares of contribution of capital and labour inputs to the economic growth were 50.9 per cent and 18.8 per cent respectively, and the sum of their contributions was 69.7 per cent. At the same time, the average growth rate of productivity was 2.53 per cent, and it's share of contribution to economic growth was 30.3 per cent, lower

Table 1 Growth rates of aggregate output, input and productivity, 1953-1990

	1953-1990[1]	1953-1978	1979-1990	"1st F"	"4th F"	"5th F"	"6th F"	"7th F"
Value added	0.0678	0.0592	0.0835	0.0830	0.0570	0.0620	0.0960	0.0740
Capital input	0.0989	0.1023	0.0915	0.1640	0.0857	0.0862	0.0824	0.1000
Labour input	0.0273	0.0263	0.0293	0.0250	0.0230	0.0210	0.0330	0.0270
Contribution of capital input	0.0509	0.0551	0.0425	0.0837	0.0510	0.0470	0.0389	0.0435
Contribution of labour input	0.0132	0.0121	0.0157	0.0122	0.0093	0.0095	0.0174	0.0153
Rate of productivity growth	0.0037	-.0080	0.0253	-.0129	-.0033	0.0055	0.0397	0.0152
Capital productivity	-.0311	-.0435	-.0800	-.0810	-.0287	-.0242	0.0136	-.0260
Labour productivity	0.0405	0.0329	0.0542	0.0580	0.0340	0.0410	0.0630	0.0470
The shares of contribution of two inputs and productivity growth in output growth (%)								
Capital input	0.7507	0.9307	0.5090	1.0084	0.8947	0.7581	0.4052	0.5878
Labour input	0.1947	0.2044	0.1880	0.1470	0.1632	0.1532	0.1813	0.2068
Productivity growth	0.0546	–	0.3030	–	–	0.0887	0.4135	0.2054

Notes: (1) Annual average growth rate over 38 years using 1952 as the base year.
"The First Five-year Plan" is abbreviated as "1st F", and so on.

than that of capital but higher than that of labour. By such comparison, it is shown that the reform and open-door policy has promoted technological progress and a rational utilization of resources in China as witnessed by the increase in the proportion of contribution of productivity to economic growth.

For the First and the Fourth Five-year Plan, the growth rates of productivity were negative. The contribution of capital to economic growth exceeded or approached the economic growth. The middle of the Fifth Five-year Plan (1976-1980) was the critical year when policy changed. In these five years, the proportions of the contribution of capital and labour to economic growth were 75.8 per cent and 15.32 per cent respectively, and that of productivity was 8.88 per cent. Because of the adjustment of the economic policy, the growth of productivity was negative in 1981 and negligible in 1982. Rapid development appeared in the last three years of the Sixth Five-year Plan (1981-1985). As a whole, these five years made up the golden age of the entire period. In this period, the average growth rate of capital stock was 8.24 per cent and the contribution of capital to economic growth was 40.52 per cent. As for labour, the contribution was 3.3 per cent and 18.13 per cent respectively. Concomitantly, the average growth rate of productivity increased to 3.9 per cent, its contribution to economic growth was 41.35 per cent, exceeding the contribution of capital. This was the outcome of the reform and open-door policies, which introduced the market mechanism and brought all positive factors into play. Resources were more efficiently utilized. Other favourable factors were the expansion of international economic exchange and, domestically, the encouragement of technical development and innovation. In the first three years of the Seventh Five-year Plan (1986-1990), the disequilibrium with respect to aggregate demand and supply was exacerbated, and inflation reached the highest level in the history of new China. In the remaining two years of this period, a deflationary policy induced a slowdown in demand and the market was depressed, resulting in a decrease in production. The average rate of economic growth in the Seventh Five-year Plan was 7.4 per cent, i.e., 23 per cent less than that of the Sixth Five-year Plan. The average growth rate of capital stock was 10 per cent, 21 per cent higher than that of the Sixth Five-year Plan. The contributions of capital and labour to economic growth were 58.78 per cent and 20.68 per cent respectively, and the contribution of productivity was 20.54 per cent. Although the average rate of economic growth in the Seventh Five-year Plan was only 77.08 per cent of that of the Sixth Five-year Plan according to the last column in Table 1, the average growth rate of capital stock was 21 per cent higher than that in the Sixth Five-year Plan, because of excessive investment at the beginning. Capital was injected into the economy to stimulate the depressed market. While production went up somewhat, inventories continued to increase and capital was under-utilized.

(2) The whole period of 38 years is divided into seven sub-periods in order to reduce the influence of violent economic fluctuations on the analysis of the sources of economic growth. In each sub-period, the economy either expanded or declined continuously so that the terminal year of each sub-period was either at the peak or the trough of the business cycle of two adjacent sub-periods. The rates of economic growth and productivity growth of the seven sub-periods are presented in Table 2. There are three sub-periods with negative growth, and their corresponding growth rates of productivity are also negative. The reasons for these three sub-periods of negative economic growth and productivity are non-economic, e.g., natural disasters and misguided policy in the second period (1960-1962), and the political disturbances of the "Cultural Revolution" in the other two sub-periods (1967-1968, and 1976).

The first column in Table 2 reports the data of the First Five-year Plan and the first two years of the Second Five-year Plan (1953-1959). The average rate of economic growth was 9.93 per cent. The capital stock increased continuously with an average growth rate of 18.7 per cent, so that the contribution of capital to economic growth was 95.67 per cent. It seems that the capital input itself propelled economic growth in this period. The third column presents the data of the period of recovery (1963-1966)

Table 2 Growth rates of aggregate output, input and productivity of seven sub-periods in 1953-1990

	1953-1959	1960-1962	1963-1966	1967-1968	1969-1975	1976	1977-1990
Value added	0.0993	-.1388	0.1421	-.0715	0.0960	-.0269	0.0850
Capital input	0.1870	0.0807	0.0582	0.0340	0.0805	0.0700	0.0909
Labour input	0.0382	-.0089	0.0308	0.0346	0.0277	0.0215	0.0277
Contribution of capital input	0.0950	0.0385	0.0306	0.0180	0.0479	0.0400	0.0435
Contribution of labour input	0.0188	-.0460	0.0146	0.0163	0.0112	0.0092	0.0144
Rate of productivity growth	-.0145	-.1727	0.0969	-.1058	0.0369	-.0761	0.0271
Capital productivity	-.0877	-.2195	0.0839	-.1055	0.0155	-.0969	-.0057
Labour productivity	0.0611	0.1299	0.1113	-.1061	0.0683	-.0484	0.0575
The shares of contribution of two inputs and productivity growth in output growth (%)							
Capital input	0.9567	–	0.2153	–	0.4990	–	0.5117
Labour input	0.1893	–	0.1027	–	0.1167	–	0.1694
Productivity growth	–	–	0.6819	–	0.3843	–	0.3189

after the natural disasters. The average rate of economic growth was 14.21 per cent; such a rate was high relative to the poor economic performance of 1962. In fact the level of economic activities in 1966 was 116.4 per cent as high as that in 1959. The growth of capital input was slower than that of the economy. Hence, the contribution of capital to economic growth was only 21.53 per cent in this sub-period, far lower than that of productivity (68.19 per cent). Clearly, there was a lagged effect of investments in the last sub-period on output. The average rate of economic growth in the fifth sub-period was 9.6 per cent, and the average growth rates of the capital stock and labour were 8.05 per cent and 2.77 per cent respectively. The contributions of capital and labour to economic growth were 49.9 per cent and 11.67 per cent respectively; the contribution of productivity growth was 38.43 per cent, falling between those of capital and labour. The reason of high contribution of productivity in this sub-period was really similar to that in the third one. The growth rate was relatively high in comparison with the economic depression in 1968. The economic growth in the seventh sub-period (1977-1990) was stable because of the implementation of the reform and open-door. The average rate of economic growth was 8.5 per cent; the average growth rate of capital stock was 9.09 per cent; the average labour growth rate was 2.77 per cent; the contributions of capital and labour to economic growth were 51.17 per cent and 16.96 per cent respectively; the contribution of productivity to economic growth was 31.89 per cent. This pattern of growth was the result of the "reform and open-door" policy.

(3) No matter how the sub-periods are divided, the small positive average growth rate of productivity for the whole period conceals the negative growth rates of more than half of the sub-periods; the same is true with respect to the whole period and sub-periods whose productivity growth also conceals the negative rates of the same years. In order to analyse more clearly, the growth rates of the economy and productivity in the 38-year period (1953-1990) are presented in Table 3. From Table 3, it can be seen that there are six years with negative economic growth and

16 years with negative productivity growth of which 13 years fall into the pre-reform era. Negative growth in 1981, 1989 and 1990 was the result of economic factors. Simple statistical analysis uncovers the following tendencies.

Table 3 Aggregate output, input and productivity by year, 1953-1990

Year	Rate of growth			Contribution to growth in output		
	Output	Labour	Capital	Labour input	Capital input	Rate of productivity growth
1953	0.1234	0.0289	0.2083	0.0136	0.1104	-0.0006
1954	0.0559	0.0257	0.1551	0.0126	0.0790	-0.0357
1955	0.0621	0.0200	0.1342	0.0097	0.0688	-0.0164
1956	0.1319	0.0237	0.1531	0.0112	0.0809	0.0398
1957	0.0438	0.0300	0.1694	0.0149	0.0852	-0.0563
1958	0.1997	0.0839	0.2206	0.0416	0.1114	0.0469
1959	0.0782	0.0555	0.2683	0.0276	0.1346	-0.0840
1960	-0.0144	-0.0086	0.2091	-0.0044	0.1033	-0.1123
1961	-0.3346	-0.0107	0.0339	-0.0055	0.0165	-0.3456
1962	-0.0675	-0.0073	-0.0009	-0.0039	-0.0004	-0.0632
1963	0.1019	0.0157	0.0253	0.0084	0.0117	0.0818
1964	0.1530	0.0340	0.0422	0.0173	0.0207	0.1150
1965	0.1564	0.0371	0.0869	0.0174	0.0461	0.0929
1966	0.1572	0.0364	0.0786	0.0159	0.0442	0.0971
1967	-0.0752	0.0355	0.0378	0.0157	0.0210	-0.1119
1968	-0.0677	0.0337	0.0303	0.0158	0.0160	-0.0995
1969	0.1769	0.0374	0.0412	0.0170	0.0225	0.1374
1970	0.2058	0.0387	0.0940	0.0156	0.0560	0.1372
1971	0.0874	0.0369	0.0923	0.0143	0.0566	0.0165
1972	0.0280	0.0222	0.0798	0.0086	0.0482	-0.0288
1973	0.0797	0.0154	0.0945	0.0061	0.0559	0.0168

Table 3 (Continued)

1974	0.0114	0.0212	0.0802	0.0086	0.0474	-0.0446
1975	0.0799	0.0220	0.0814	0.0091	0.0476	0.0232
1976	0.0269	0.0215	0.0700	0.0092	0.0399	-0.0760
1977	0.0750	0.0175	0.0753	0.0078	0.0430	0.0250
1978	0.1157	0.0184	0.0996	0.0080	0.0562	0.0515
1979	0.0733	0.0221	0.1036	0.0099	0.0572	0.1062
1980	0.0751	0.0285	0.0827	0.0136	0.0431	0.0184
1981	0.0439	0.0332	0.0662	0.0166	0.0330	-0.0057
1982	0.0837	0.0126	0.0676	0.0064	0.0329	0.0444
1983	0.0982	0.0518	0.0773	0.0266	0.0377	0.0339
1984	0.1361	0.0317	0.0877	0.0168	0.0409	0.0784
1985	0.1197	0.0366	0.1132	0.0202	0.0507	0.0488
1986	0.0798	0.0319	0.1242	0.0178	0.0549	0.0071
1987	0.1045	0.0290	0.0989	0.0163	0.0432	0.0450
1988	0.1034	0.0296	0.1000	0.0168	0.0432	0.0435
1989	0.0349	0.0234	0.0907	0.0134	0.0387	-0.0172
1990	0.0491	0.0214	0.0859	0.0120	0.0375	-0.0004

In the 32 years with positive economic growth, there are 15 years with contribution of capital to economic growth higher than 60 per cent, and seven years with the contribution higher than economic growth itself because of the negative productivity. There are eight years in which the contribution of capital is larger than 40 per cent but less than 60 per cent, four years with that between 30 per cent and 40 per cent, and five years with that below 30 per cent. A year with a lower contribution of capital is always followed by a year with negative output growth, and correspondingly with a large proportion of contribution by productivity. This is clear from the analysis of the contribution of productivity. Of the 23 years with positive growth of productivity, there are eight years in which the contribution of productivity to output growth is greater than 50 per cent. Among these eight years, six years are in the period from 1963 to 1970, i.e., the restoration period just after the sharply negative growth of output caused by natural disasters and the chaos of the "Cultural Revolution," and the remaining two years are after 1978. There are seven years with the contribution of productivity between 30 per cent and 50 per cent, with five years after 1978. Finally, there are eight years with the contribution of productivity below 30 per cent.

From our analysis, growth may be attributed to economic as well as non-economic factors. With respect to economic factors, capital input is the major factor, followed by labour input. As a whole, the growth rate of productivity is the least important. However, its contribution is larger than that of labour input or even than that of capital in some years or sub-periods. It is worth noting that the contribution of productivity to economic growth markedly increased in the 1980s, showing that technological progress was induced by the improvement in the quality of capital and labour and enhanced productivity of capital and labour. This tendency cannot be ignored.

III. Output Growth of the Chinese Industrial Sector

After the 1970s, one major accomplishment in the analysis of output growth at the industry level is that intermediate, capital and labour inputs are treated symmetrically. Output is represented as a function of intermediate input, capital and labour inputs and time. Time is an indicator of technical change. The growth rate of output may be decomposed into the contribution of intermediate, capital and labour inputs and the growth of productivity. The sectoral production function approach pertains to a producer's behaviour model, in a general equilibrium context. The economic analysis of industrial sectors employs time-series data from input-output tables. We have chosen only the period 1981-1987 and employed the Lagrange method introduced by

Masahiro Kuroda of Keio University (Japan) to estimate the transaction matrix for 1982, 1984, 1985, 1986 from 1981, 1983 and 1987. Then, we have transferred the matrix into the "USE" table through the "MAKE" table for each year.

We have obtained the contributions of three inputs for sectoral outputs. They are the products of the growth rates of inputs and their shares in the value of total output. Table 4 presents the output, contributions of inputs and growth of productivity of 34 sectors, and compares the growth rates of output, contributions of intermediate input, capital and labour inputs and growth rates of productivity during the 1981-1987 period. In 33 sectors, the intermediate input, capital and labour inputs are predominant sources of the growth of output. Of the three inputs, the contribution of intermediate input exceeds 50 per cent of the growth of output in 25 sectors and is the most important factor among the three input factors. To compare capital input with labour input, the contribution of capital input to output growth in 25 sectors is more than the contribution of labour input. There are only two sectors in which productivity growth is the major source of output growth, namely, the miscellaneous manufacturing sector and the other services sector.

Table 4 Growth in sectoral outputs and their sources, 1981-1987

		Contribution to growth in output			
	Rate of output growth	Intermediate input	Capital input	Labour input	Rate of productivity growth
Agriculture, forestry and fisheries	0.0702	0.0171	0.0325	0.0088	0.0118
Metal mining	0.0324	0.0436	-0.2730	0.0131	0.0029
Coal mining	0.0583	0.0084	0.0121	0.0323	0.0054
Crude petroleum and natural gas	0.0495	0.0134	0.0788	0.0080	-0.0506
Non-metallic mining	0.0763	0.0509	0.0115	0.0448	-0.0308

Table 4 (Continued)

Construction	0.1345	0.0912	0.0060	0.0321	0.0052
Food and kindred products	0.1087	0.0831	0.0126	0.0106	0.0024
Tobacco manufactures	0.1008	0.0506	0.0922	0.0023	-0.0443
Textile products	0.1132	0.0680	0.0264	0.0093	0.0096
Apparels and other textile products	0.1282	0.0624	0.0368	0.0099	0.0191
Lumber and wood products	0.1155	0.0947	0.0173	0.0030	0.0005
Furniture and fixtures	0.1500	0.0754	0.0313	0.0104	0.0329
Paper and allied products	0.1208	0.0667	0.0162	0.0067	0.0312
Printing and publishing	0.1521	0.0802	0.0368	0.0150	0.0201
Chemicals and allied products	0.1439	0.1083	0.0141	0.0074	0.0141
Petroleum refining	0.0997	0.0427	0.0258	0.0083	0.0228
Rubber and plastic products	0.1705	0.1078	0.0303	0.0102	0.0222
Leather and leather products	0.1428	0.0851	0.0241	0.0091	0.0245
Stone, clay and glass products	0.1357	0.0947	0.0352	0.0270	-0.0212
Primary metals	0.1047	0.0789	0.0215	0.0054	-0.0012
Fabricated metal products	0.1332	0.0909	0.0137	0.0080	0.0206
Machinery, except electrical	0.2006	0.1356	0.0048	0.0090	0.0512
Electrical machinery	0.2118	0.1521	0.0251	0.0053	0.0302
Motor vehicles	0.1975	0.1231	0.0167	-0.0015	0.0593
Other transportation equipment	0.1034	0.0557	-0.0064	0.0186	0.0355
Miscellaneous manufacturing	0.1602	0.0552	0.0039	-0.0078	0.1089

Table 4 (Continued)

Other manufacturing	0.1529	0.0823	0.0210	0.0047	0.0449
Transportation	0.1146	0.0575	0.0515	0.0176	-0.0120
Communication	0.1146	0.0426	0.0772	0.0202	-0.0254
Electric utilities	0.0941	0.0788	0.0569	0.0049	-0.0464
Trade	0.1084	0.0600	0.0071	0.0196	0.0218
Other services	0.2105	0.0076	0.0879	0.0041	0.1108
Finance, insurance	0.1282	0.0497		0.0041	
Government	0.1800	0.0389		0.0334	

We have employed the method introduced by Jorgenson of Harvard University (U.S.) to analyse sectoral growth. The contribution of each input may be decomposed into the contribution of the change in quality and quantity. For the period 1981-1987, the results of the decomposition exercise for the 34 sectors are listed separately in Table 5. From Table 5, we know that the contribution of quality change to output growth is not a major component among the contributions of the three inputs. Ignoring quality change does not affect the relative contribution of the three inputs and productivity. The contribution of quality change is negligible because: (1) the period of our study consists of seven years only, (2) owing to the egalitarian wage system, the price of labour (i.e., wage rate) is not a reliable weight for estimating the quality of labour input, (3) similarly, due to the problems in the price system, the investment system and the tax system of China, it is difficult for us to get accurate rental prices of assets to estimate the quality of capital.

Table 5 Contributions of input quality to growth in sectoral output: rate of growth, 1981-1987

	Average annual rates of growth						
	Quality of intermediate input	Unweighted intermediate input	Quality of capital stock	Capital stock	Quality of labour input	Labour input	Rate of productivity growth
Agriculture, forestry and fisheries	-0.0046	0.0217	-0.0096	0.0421	0.0000	0.0088	0.0118
Metal mining	-0.0042	0.0478	-0.0170	-0.0102	0.0026	0.0105	0.0029
Coal mining	-0.0106	0.0190	-0.0020	0.0142	0.0075	0.0248	0.0054
Crude petroleum and natural gas	-0.0100	0.0234	0.0026	0.0762	0.0006	0.0074	-0.0506
Non-metallic mining	-0.0010	0.0519	-0.0023	0.0137	0.0054	0.0394	-0.0308
Construction	-0.0302	0.1214	0.0014	0.0046	-0.0004	0.0325	0.0052
Food and kindred products	0.0014	0.0817	0.0008	0.0118	0.0004	0.0102	0.0024
Tobacco manufactures	0.0002	0.0504	0.0060	0.0862	0.0000	0.0023	-0.0443
Textile products	-0.0023	0.0703	0.0019	0.0245	-0.0005	0.0098	0.0096
Apparels and other textile products	0.0008	0.0616	0.0010	0.0358	-0.0034	0.0133	0.0191
Lumber and wood products	0.0018	0.0929	-0.0005	0.0178	-0.0004	0.0034	0.0005
Furniture and fixtures	-0.0039	0.0793	0.0063	0.0250	-0.0007	0.0111	0.0329
Paper and allied products	-0.0121	0.0788	0.0016	0.0146	0.0000	0.0067	0.0312
Printing and publishing	-0.0039	0.0841	0.0012	0.0356	0.0011	0.0139	0.0201
Chemicals and allied products	-0.0032	0.1115	-0.0017	0.0158	-0.0009	0.0083	0.0141
Petroleum refining	-0.0131	0.0558	0.0029	0.0230	-0.0009	0.0093	0.0228

Table 5 (Continued)

Rubber and plastic products	-0.0051	0.1129	0.0023	0.0280	-0.0012	0.0114	0.0222
Leather and leather products	-0.0006	0.0857	-0.0010	0.0251	-0.0007	0.0097	0.0245
Stone, clay and glass products	-0.0087	0.1034	-0.0013	0.0365	0.0018	0.0252	-0.0212
Primary metals	-0.0044	0.0833	0.0011	0.0204	-0.0004	0.0058	-0.0012
Fabricated metal products	-0.0087	0.0996	0.0020	0.0118	0.0000	0.0080	0.0206
Machinery, except electrical	-0.0105	0.1461	-0.0024	0.0073	-0.0007	0.0097	0.0512
Electrical machinery	-0.0118	0.1629	-0.0010	0.0261	-0.0619	0.0672	0.0302
Motor vehicles	-0.0100	0.1331	-0.0056	0.2222	-0.0004	-0.0011	0.0593
Other transportation equipment	-0.0130	0.0687	-0.0060	0.0000	-0.0016	0.0202	0.0355
Miscellaneous manufacturing	-0.0161	0.0713	-0.0078	0.0177	-0.0004	-0.0075	0.1089
Other manufacturing	-0.0203	0.1026	-0.0007	0.0217	0.0001	0.0046	0.0449
Transportation	-0.0049	0.0624	0.0079	0.0435	-0.0013	0.0189	-0.0120
Communication	-0.0054	0.0480	0.0289	0.0482	-0.0035	0.0237	-0.0254
Electric utilities	0.0236	0.0552	0.0047	0.0522	-0.0012	0.0060	-0.0464
Trade	-0.0055	0.0654	-0.0002	0.0073	0.0000	0.0196	0.0218
Other services	-0.0151	0.0228	-0.0027	0.0906	0.0000	0.0041	0.1108
Finance, insurance	-0.0068	0.0566	0.0000	0.0000	0.0053	-0.0091	
Government	-0.0096	0.0486	0.0000	0.0000	0.0020	0.0341	

IV. Methodology and Data Manipulation

In this chapter, even though we have employed the methodology developed in Western countries, we still insist on taking note of economic theories developed in China and the specificity of China's economic system. Most of the indicators have the same names as those used in Western countries and they all belong to the SNA system. But their meanings are not exactly the same. For example, the private domestic investment in Western countries in GNP corresponds to gross accumulation in our country; it mainly includes the accumulation by the state and the collective sectors. Value added as defined in China is different from that in Western countries. However, it should not impede us from using the same methodology in different countries whose economic theories are based on different foundations. The results from the study may be analysed from different perspectives.

Methodology and Data at the Aggregate Level

Methodology

Our aggregate model of production is based on a production function, characterized by constant returns to scale:

$$V = F(K, L, T)$$

where V is value added, K is capital, L is labour input, and T is time. The share of capital (V_K) and labour inputs (V_L) in the value added is defined as follows:

$$V_K = P_K K/V, \text{ and } V_L = P_L L/V$$

where $P_K K$ and $P_L L$ are the outlays of capital and labour inputs; P_K and P_L are the prices of capital and labour inputs. Necessary conditions for producer equilibrium are given by equalities between V_K and V_L on the one hand and the elasticities of output with respect to the inputs, on the other:

$$V_K = \partial LnV(K, L, T)/\partial LnK, \; V_L = \partial LnV(K, L, T)/\partial LnL.$$

At the same time, the growth rate of productivity, V_T, is the growth rate of value added with respect to time, holding capital and labour inputs constant:

$$V_T = \partial LnV(K, L, T)/\partial T.$$

The translog production function is employed:

$$V = \exp[\alpha_0 + \alpha_K lnK + \alpha_L lnL + \alpha_T T + 0.5\beta_{KK}(lnK)^2 + \beta_{KL}(lnK)(lnL) + \beta_{KT}(lnK)T + 0.5\beta_{LL}(lnL)^2 + \beta_{LT}(lnL)T + \beta_{TT}T^2]$$

where α_0, α_K, α_L, α_T, β_{KK}, β_{LL}, β_{TT}, β_{KL}, β_{KT}, β_{LT} are parameters to be estimated.

Under constant returns to scale:

$$\alpha_K + \alpha_L = 1$$

$$\beta_{KK} + \beta_{KL} = 0$$

$$\beta_{KL} + \beta_{LL} = 0$$

$$\beta_{KT} + \beta_{LT} = 0.$$

The unbiased estimates of the parameters α_0, α_K, α_T, β_{KK}, β_{KT}, β_{TT} can be derived by econometric methods using time-series data. The average rate of productivity growth (V_T) (T_1 to T_n) can be computed based on these estimated parameters:

$$V_T = \alpha_T + \beta_{KT} lnK + \beta_{LT} lnL + \beta_{TT} T.$$

The accuracy of these estimates can be improved by introducing quadratic components to the production function. In general, we calculate the rate of productivity growth between two adjacent years T and (T-1) by the following formula:

$$\overline{V}_T = lnV(T) - lnV(T-1) - V_K[lnK(T) - lnK(T-1)] - V_L[lnL(T) - lnL(T-1)]$$

where $\overline{V}_T$ is the average value of V(T) and V(T-1), and,

$$\overline{V}_K = 0.5[V_K(T) + V_K(T-1)], \; \overline{V}_L = 0.5[V_L(T) + V_L(T-1)].$$

This is the formula for computing the rate of productivity growth between two adjacent years T and (T-1), and it can also be used as another kind of method to estimate the average rate of productivity growth of n-year period (T_1 to T_n).

Data Processing

The aggregate output is equal to value added or GNP. Chinese GNP figures have been released annually since 1978. The GNP data before 1978 have been revised, taking note of the differences between national income as defined in MPS and gross national product in SNA. Annual GNP data from 1952 to 1990 are then estimated and are deflated by a price index with 1978 as the base year, i.e., the price index of 1978 is 1.0.

Capital input is the total capital stock of society consisting of fixed assets and current assets. The annual investment data used to compute the real capital stock and the initial capital stock (1952) are deflated by a price index of investment with 1978 as 1.0 since the composition and prices of capital goods changed over the years.

Finally, we deduct the depreciation funds of each year from that year's fixed assets, according to China's current depreciation method.

Labour input is expressed as the flow of services which is the quantity of labour employed directly in the manufacturing and services sectors. It consists of salaried workers, the income of farmers from the sale of agricultural products, and self-employed labourers engaged in commerce and production. Using data from sample surveys, the flow of labour services in a certain period can be deduced by deducting from total labour hours the following items: (1) regular holidays and vacations of wage employees, as well as hours lost due to work stoppage, sick leave and personal leave, and time spent on voluntary work, and (2) time of self-employed peasants and individuals not used in production.

Outlays of primary factor inputs consist of outlays of capital input and labour input. At the aggregate level, the outlay of capital input includes profits and the depreciation allowance of fixed

assets. The former is derived from the sum of profit and tax as defined in our accounting system by deducting indirect taxes; the depreciation of housing provided by enterprises to workers is transferred to outlay of labour input as the "implicit income" of workers.

The outlay of labour input includes wages in any form paid to workers, and implicit incomes, e.g., all other expenses paid by firms on housing, education and transportation subsidies. It also includes the net incomes of self-employed peasants and individuals derived from the sale of agricultural products or individual business. In the reform period, part of their net incomes is derived from investments in capital goods, e.g., farm machines by peasants and inventories of individual businessmen and should thus be regarded as profits classified as income from capital. The data are adjusted in response to the practical situation in the reform era because the workers with capital income constitutes about 75 per cent of the labour force. The proportion of their incomes to labour income has already risen from 52.6 per cent in 1977 to 64 per cent in 1990. Part of their incomes should not be included as income from capital input in the SNA system.

Methodology and Data at the Sectoral Level

Methodology

As summarized above, frontier research on productivity and economic growth treats all three inputs at the sectoral level symmetrically. We have employed this advanced methodology, and the results are presented in Tables 4 and 5. This methodology is based on a model of producer behaviour which is the same as that in Jorgenson et al. (1987) "Productivity and U.S. Economic Growth."

$$Z_i = F_i(X_i, K_i, L_i, T), \qquad (i = 1, 2, ..., n).$$

This model assumes homogeneous production functions for all sectors where $\{Z_i\}$ is output; $\{X_i\}$, $\{K_i\}$ and $\{L_i\}$ are intermediate, capital and labour inputs of the ith sector; T is time. We can define the shares of intermediate, capital and labour inputs, $\{v_X^i\}$, $\{v_K^i\}$ and $\{v_L^i\}$, in the value of output by:

$$v_X^i = \frac{P_x^i X_i}{q_i Z_i},\ v_K^i = \frac{P_k^i K_i}{q_i Z_i},\ v_L^i = \frac{P_L^i L_i}{q_i Z_i}$$

where $\{q_i\}$, $\{p_X^i\}$, $\{p_K^i\}$ and $\{p_L^i\}$ denote the prices of output and intermediate, capital, and labour inputs respectively.

The necessary conditions of producer equilibrium are given by equalities between the share of each input in the value of output and the elasticities of output with respect to the inputs:

$$v_X^i = \frac{\partial lnZ_i}{\partial lnX_i}(X_i, K_i, L_i, T),$$

$$v_K^i = \frac{\partial lnZ_i}{\partial lnK_i}(X_i, K_i, L_i, T),$$

$$v_L^i = \frac{\partial lnZ_i}{\partial lnL_i}(X_i, K_i, L_i, T), \qquad (i = 1, 2, ..., n).$$

We can define the rate of productivity growth, $\{v_T^i\}$, as the growth of output with respect to time when intermediate, capital and labour inputs are constant:

$$v_T^i = \frac{\partial lnZ_i}{\partial T}(X_i, K_i, L_i, T), \qquad (i = 1, 2, ..., n).$$

In general, we calculate the rate of productivity growth between two adjacent years T and T-1, using the following expression:

$$\overline{V}_T^i = [lnZ_i(T) - lnZ_i(T-1)] - \overline{V}_X^i\,[lnX_i(T) - lnX_i(T-1)]$$
$$- \overline{V}_K^i\,[lnK_i(T) - lnK_i(T-1)] - \overline{V}_L^i\,[lnL_i(T) - lnL_i(T-1)]$$
$$(i = 1, 2, ..., n).$$

The weights $\overline{V}_X^i$, $\overline{V}_K^i$, $\overline{V}_L^i$ are average values of intermediate input, capital and labour input with respect to T and T-1 years, i.e.,:

$$\overline{V}_X^i = \frac{1}{2}[V_X^i(T) + V_X^i(T-1)]$$

$$\overline{V}_K^i = \frac{1}{2}[V_K^i(T) + V_K^i(T-1)]$$

$$\overline{V}_L^i = \frac{1}{2}[V_L^i(T) + V_L^i(T-1)].$$

At the sectoral level, different kinds of each input are aggregated to arrive at the following input aggregates:

$$X_i = X_i(X_{1i}, X_{2i}, \ldots, X_{ni}),$$

$$K_i = K_i(K_{1i}, K_{2i}, \ldots, K_{pi}),$$

$$L_i = L_i(L_{1i}, L_{2i}, \ldots, L_{qi}), \qquad (i = 1, 2, ..., n)$$

where $\{X_{ji}\}$ is the jth commodity (j=1, 2, ..., n) allocated into the ith sector. $\{K_{ki}\}$ is the kth type of capital used in the ith sector, (k=1, 2, ..., p), and $\{L_{li}\}$ (i=1, 2, ..., q) is the lth type of labour employed in the ith sector. It is assumed that the production function is separable in intermediate, capital and labour inputs. However, the input aggregates for each sector are characterized by constant returns to scale. We can define the shares of the different kinds of intermediate, capital and labour inputs, in the value of the corresponding aggregates by:

$$v_{Xj}^i = \frac{p_{Xj}^i X_{ji}}{p_X^i X_i}, \qquad (i, j = 1, 2, ..., n),$$

$$v_{Kk}^i = \frac{p_{Kk}^i K_{ki}}{p_K^i K_i}, \qquad (i = 1, 2, ..., n;\ k = 1, 2, ..., p),$$

$$v_{Ll}^i = \frac{p_{Ll}^i L_{li}}{p_L^i L_i}, \qquad (i = 1, 2, ..., n;\ l = 1, 2, ..., q)$$

where $\{p_{Xj}^i\}$, $\{p_{Kk}^i\}$, $\{p_{Ll}^i\}$ are the prices of individual intermediate, capital and labour inputs.

Necessary conditions for producer equilibrium are given by equalities between the shares of the individual inputs in the value of the corresponding aggregates and the elasticities of the aggregate with respect to individual inputs:

$$v_{Xj}^i = \frac{\partial lnX_i}{\partial lnX_{ji}}(X_{1i}, X_{2i}, ..., X_{ni}).$$

To construct an index of intermediate input for two adjacent years, T and T-1, for each industrial sector, a translog quantity index based on individual intermediate inputs is adopted:

$$lnX_i(T) - lnX_i(T-1) = \sum \bar{v}_{Xj}[lnX_{ji}(T) - lnX_{ji}(T-1)], \quad (i = 1, 2, ..., n)$$

where the weights are given by the average share of each components in the value of sectoral intermediate outlay:

$$\bar{v}^i_{Xj} = \frac{1}{2}[v^i_{Xj}(T) + v^i_{Xj}(T-1)], \qquad (i, j = 1, 2, ..., n),$$

and

$$v^i_{Xj} = \frac{p^i_{Xj}X_{ji}}{\sum_j p^i_{Xj}X_{ji}}, \qquad (i, j = 1, 2, ..., n)$$

where $\{p^i_{Xj}\}$ is producer's prices. Similarly, the index of capital input between two adjacent years T and T-1 for each industrial sector is a translog quantity index of individual capital inputs:

$$lnK_i(T) - lnK_i(T-1) = \sum \bar{v}^i_{Kk}[lnK_{ki}(T) - lnK_{ki}(T-1)], \quad (i = 1, 2, ..., n)$$

where the weights are given by the average share of each components in the value of sectoral property compensation:

$$\bar{v}^i_{Kk} = \frac{1}{2}[v^i_{Kk}(T) + v^i_{Kk}(T-1)], \quad (i = 1, 2, ..., n; k = 1, 2, ..., p),$$

and

$$v^i_{Kk} = \frac{p^i_{Kk}K_{ki}}{\sum p^i_{Kk}K_{ki}}, \quad (i = 1, 2, ..., n; k = 1, 2, ..., p)$$

where $\{p^i_{Kk}\}$ is the price of capital stock which is calculated by depreciation of capital goods and profits, etc. Finally, the index of labour input between two adjacent years, T and T-1, for each industrial sector is a translog quantity index of individual labour input:

$$lnL_i(T) - lnL_i(T-1) = \sum \bar{v}^i_{Ll}[LnL_{li}(T) - lnL_{li}(T-1)], \quad (i = 1, 2, ..., n),$$

where weights are given by average share of each component in the value of sectoral labour compensation:

$$\bar{v}^i_{Ll} = \frac{1}{2}[v^i_{Ll}(T) + v^i_{Ll}(T-1)], \quad (i = 1, 2, ..., n; l = 1, 2, ..., q),$$

and

$$v^i_{Ll} = \frac{p^i_{Ll}L_{li}}{\sum p^i_{Ll}L_{li}}, \quad (i = 1, 2, ..., n; l = 1, 2, ..., q)$$

where $\{p^i_{Ll}\}$ is the price of labour (i.e., wage rate).

Data Processing

Data manipulations at the sectoral level are consistent with those at the aggregate level, with some exceptions to be explained below.

Sectoral Output

In the general equilibrium model, sectoral output in total industry output is the sum of intermediate input and value added. The price of output includes the tax paid by the producer but excludes the balance of trade and transportation expenses. These prices are called producers' prices. The value of sectoral output may be found in the input-output table, where the value of output is in terms of both current and constant prices. Under constant price, value output may reflect the changes in the increase and decrease of sectoral output among different periods. The ratio of the value of output in current prices to that in constant prices is the price index, which reflects the change in the price level of the sectoral output affected by inflation or changes in the quantities of inputs used. We have measured the price indexes for 34 sectors and 34 commodities using input-output tables in cooperation with the State Statistical Bureau of China. Those indexes are employed to arrive at the results presented in Tables 4 and 5. The value of output in constant prices are used to calculate the rate of growth for each sector. The value of output in current prices is used to calculate the share of intermediate input, capital and labour inputs in the value of output for each sector.

Intermediate Input

Data on intermediate inputs are from the time series included in the "USE" table (1981-1987). Thirty-four commodities are distributed to 34 sectors and final demand. The various commodities allocated to each sector make up the intermediate input of the sector. The prices of inputs are the producers' prices. In the input-output table, because the consumer prices have been decomposed into producers' prices, transportation expenses and balance of trade in each commodity they are regarded as input of trade, and the sum of transportation expenses in each commodity is the input of transportation.

The unweighted index of intermediate input for each sector is the sum of all commodities taken as inputs. The quality of intermediate input is defined as the ratio of the translog index number to the unweighted index. The contribution of intermediate input growth to output growth is decomposed into the contribution of unweighted intermediate input change and quality change of intermediate input. The results are listed in Table 5.

Capital Input

Capital service flow is the volume of capital input, which is derived from the price of capital stock and the value of capital stock. The price of capital stock in our study is computed using data on depreciation funds and profits. Rental price was used in Jorgenson's study (1987). The capital stock include fixed assets and current assets. The fixed assets is a weighted sum of past investments. The weight is the ratio of investment to value of fixed assets each year. Fixed assets contain equipment and buildings. The value of depreciation is deducted from the original value of assets (acquisition price of assets) year by year. The value of current assets is the sum of inventories, including materials, semi-manufactured goods and finished products. The capital stock does not contain the total value of land. Only the compensations paid to agricultural land to build factories and railways are included in the capital stock. Capital input for each sector combines

price and quantity data, cross-classified by ownership of assets and types of assets, into price and quantity indexes of capital input. Changes in the quality of capital stock represent the difference between changes in the translog quantity index of capital input and changes in an unweighted index of capital stock. Indexes of the quantity of capital input are presented in Table 4 for 34 sectors. The corresponding indexes of quality of capital and capital stock are presented in Table 5.

Labour Input

There are two kinds of workers in our country: wage earners and self-employed peasants or workers who obtain compensations from sales of their own agricultural products and non-agricultural products. The labour input for each sector combines price and quantity data, cross-classified by sex, age, education, and employment status, into price and quantity indexes of labour input. The original data come from the population census and the *Statistical Yearbook of China*. Finally, we conducted a sample survey on the changes in employees' incomes and generated time series data on the structure of five dimensions of Chinese labour (1981-1987). Sectoral labour outlays (labour compensation) are derived using input-output tables.

A measure of total labour for each sector can be derived by adding labour across all 280 categories of labour input. The quality of labour input is defined as the ratio of labour input to total labour. Changes in the quality of total labour represent the difference between changes in translog quantity index of labour input and changes in an unweighted index of total labour. These indexes are presented in Tables 4 and 5.

V. Concluding Remarks

1. With reference to Tables 1-5, we estimate quantitatively various indicators of China's economic growth:

(i) From 1952 to 1990, China's economy develops rapidly. The mean annual growth rate reaches 6.78 per cent, which is higher than that of industrialized countries. However, it is lower than 10.2 per cent, which is the average growth rate of Japan from the mid-1960s to 1973 (see Table 6). Twelve years after implementing the open-door policy, China's economic growth remains stable and the average growth rate is 8.35 per cent. From 1978 to 1988, the average growth rate then reaches 9.18 per cent.

Table 6 Main developed countries output growth (average percentage changes at annual rates)

	United States	Japan	Germany	United Kingdom	Canada	Austria	France
1960s(c)-1973	3.8	10.2	4.6	3.3	5.1	4.5	5.9
1973-1979	2.8	3.8	2.4	1.1	4.9	3.5	3.4
1979-1985	2.0	4.1	1.5	1.2	2.3	1.8	1.1

Source: OECD Working Party No.1 of the Economic Policy Committee.

(ii) China's economic growth depends mainly on the inputs of capital and labour. The contribution of capital input to economic growth during the period 1953-1990 is 75.07 per cent and that of labour inputs is 19.47 per cent; the contribution of productivity growth to economic growth is only 5.46 per cent. This shows that we should pay more attention to the rational utilization of the resources of capital and labour in China's economic development. Table 1 shows that a capital growth rate of 9.89 per cent is necessary to maintain the employment level of the labour force. However, this can neither raise the capital productivity without significantly accelerating economic growth nor get rid of the unreasonable allocation of capital and the low efficiency of capital utilization. After 1978, the contribution of factor inputs to economic growth decreases while the contribution of productivity grows as economic growth increases to 31.88 per cent. In particular, the share of contribution of productivity growth was much higher than that of capital inputs during the Sixth Five-year Plan.

(iii) Through the short-term analysis of 34 industrial sectors from 1981 to 1987, it is obvious that intermediate inputs are the main factor of output growth, followed by capital inputs. There are only two industrial sectors whose output growth is largely due to productivity growth; eight sectors meet a negative contribution. The contribution of productivity varies significantly across sectors. The average share of contribution of productivity growth to output growth is 19.99 per cent and the mean square error is 14.94 per cent for the 24 industrial sectors with positive growth. The average share of contribution of productivity growth is 11.29 per cent, and the mean square error is 2.5 per cent for mining and raw material industries, showing that differences in productivity are small among these industries. On the contrary, the average share of the contribution of productivity growth to output growth is 33.75 per cent and the mean square error is 18.56 per cent in mechanical and electronics industries, showing great differences in these industries. The contribution of miscellaneous manufacturing industry is the highest one with 69.98 per cent because it is a hi-tech industry.

All the data mentioned above also show that, to ensure a balanced development of China, basic industry should be developed and its growth rate kept at an appropriate rate even though the productivity growth is not higher. This strategy is beneficial to the long-term economic development of China.

2. There are many factors which restrict the economic growth of China. First of all, there are non-economic factors. For example, the natural disasters which happened at the beginning of the 1960s had brought about a negative growth rate for three years. The lowest growth rate was -33.46 per cent in 1961. The economy did not recover to 1959's output level until 1965. Since investment funds had depended mainly on domestic accumulation since the Second Five-year Plan, the negative growth of the economy sharply reduced accumulation and hindered economic development. Besides, political turmoils such as the Cultural Revolution

from 1966 to 1976 which resulted in negative economic growth for three years and low growth rate for two years inflicted destructive effects on the economy. In spite of the ten years of the open-door policy, political disturbances and inflation lowered economic growth rate in 1989 to 6.85 per cent, lower than that of 1988. In 1990, the growth rate was 5.43 per cent, still lower than that of 1988. Therefore, political stability is the pre-condition for economic development.

Next in importance are economic factors, for instance, mistakes in decision-making, policy adjustments, inflation, irrational utilization of resources, distorted industrial structure, price system and imperfection of the tax system, etc. The periodic "over-investment" which appeared in 1950s, 1970s and 1980s is the main manifestation of decision-making error, intensifying the disequilibrium in aggregate supply and aggregate demand. Moreover, subsequent adjustments decreased the rate of economic growth in China. The first inflationary period occurred in the 1950s. For two consecutive years, 1958 and 1959, inflation persisted resulting in the loss of economic growth by 12.28 per cent. Irrational utilization of resources was reflected in the low growth rate of productivity. From 1953 to 1978, there were 13 years in which the productivity growth rates were negative. In the period 1978-1990, because of policy adjustments in 1981, the growth rate was lower than that in 1980 by 3.12 per cent, leading to negative growth in productivity. The slowdown in economic growth and the negative growth in productivity during 1989 and 1990 were a reflection of both political disturbances and inflation.

In conclusion, firstly, in order to maintain a stable economic expansion, a stable political environment has to be ensured. Secondly, the open-door policy has to be continued; advanced technology and management know-how from developed countries have to be introduced. Science and technology should be allowed to fully develop their potential as the most important source of productivity growth. Thirdly, the investment funds have to be allocated with a view to enhancing the rationalization of the industrial structure and to maximizing the efficiency of the national

economy. Fourthly, the decision-making process should be scientific and democratic; mistakes resulting from the centralization of decision-making power should be avoided. Fifthly, distortions in the price system should be removed, and the allocation mechanism and the tax systems improved; the vitality of large and medium-size enterprises is to be enhanced to ensure a stable growth of the national economy.

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3

Regional Disparities in the Sectoral Structure of Labour Productivity, 1985-1989

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I. Introduction

China is a large country in terms of both the size of the territory and population. As a large country, the climatic conditions and (natural) resource endowment vary substantially among different geographical regions, which for historical reasons shape the pattern of spatial distribution of economic activities, productivities, and living standards. Such patterns (affected by geographical and historical heritage), however, have rarely been able to meet the needs and desire of the central government, both politically and economically. The rectification of the deficient spatial distribution patterns has required the formulation and pursuit of regional social and economic development strategies by the central government as efficient markets did not exist and could not be trusted.

In the formulation of a regional economic development strategy, the Chinese authorities have had to face the same problem which troubles of large developing economies: the growth/equity trade-off issue symbolized the controversy over a trickle-down (or spread effect) versus a backwash effect.[1] Namely, would a discriminatory regional development strategy accelerate the economic growth of the national economy? Would it lead to regional income polarization, widening the income and productivity gaps between the privileged and under-privileged regions due to a cumulative causation effect? How long would such a stage of widening income disparities persist? Would the income gap be closed rapidly by the trickle-down effect or spread effect triggered by the privileged regions — the growth pole? Certainly, the Chinese authorities have had to search for the appropriate balance between growth and equity and to decide how to strike a balance. It should be emphasized, however, that regional development strategies in China have not been determined primarily on an economic basis. In some periods, military and ideological considerations have overshadowed economic needs.

In short, from strategic and ideological viewpoints, the Chinese authorities (under Mao Zedong) felt uneasy about the prevailing patterns of regional distribution of economic activities inherited from the Nationalist regime. Namely, production strength in terms of human capital, physical assets and technical know-how was highly concentrated in the coastal areas in the east. However, mineral ores and other natural resources were mainly deposited in the interior regions — the central and the western regions. Economically, huge disparities in the spatial distribution pattern of natural resources and processing capacity were also imposing a very heavy burden on the transportation and communications systems. Long-distance transport of mineral ores and other natural resources from the central and the western regions to the east, and the subsequent export of finished products from the east to the central and western regions enhanced transportation costs, were wasting time and adding risks to production. The concentration of industrial consumer-goods production

in the east could not take due care of the interests and needs of the people in the interior regions. The biased regional distribution of productivity gave rise to substantial inter-regional disparities in living standards. Most likely, the work incentive and initiative of the people in the interior regions were constrained by the "unfair" pattern of regional distribution of income in favour of the coastal areas.

Strategically, under the threat of potential invasion by Western countries, it was unwise to put a major proportion of China's production capacities in the coastal areas which were vulnerable to attack.[2] In case of war, every region would fight independently, implying a high degree of self-sufficiency in materials and consumer-goods supplies. Politically, the Chinese authorities (under Mao) regarded the interior regions more reliable and supportive as compared with the coastal region which had been under Western influence for a long period of time. Persistence of large income and productivity disparities between the interior and coastal regions could gradually diminish support from the former and enhance the influence of the latter, which were, however, potentially unreliable. Ideologically, Mao Zedong could not tolerate the widening inequalities between the regions and preferred local initiatives. Emphasizing local initiatives, local authorities would be allowed more autonomy for the selection of their own structure of economic activities.

Before 1978, to rectify the defects of the inherited irrational pattern of regional distribution of economic activities, the Chinese authority had pursued regional development strategies relocating production capacity, channelling relatively more resources (both physical and human) to the interior areas and granting them more autonomy to diversify their economic activities. The most dramatic had been the large-scale construction and development of the Third-Front industries starting from the mid-sixties up to the mid-seventies as a measure for war preparation against possible attack by the USA and even the USSR. Accordingly, the investment and output shares of the interior regions had increased while the income gaps (measured by per capita national income) among the East, the Middle and the West had been reduced.[3] In addition, economic activities in the relatively backward areas had become diversified and more balanced, resulting in higher productivity growth. The cost had been, however, as expected, some decrease in static allocative efficiency at the national level.[4]

After 1978, with the replacement of the ideologically inclined Maoist line of socialist construction by Deng Xiaoping's efficiency-centred modernization drive (based on enlivening the domestic economy and opening to the outside world) and the waning of war fear, the Chinese authority altered its regional development strategy. The preferential policies for fostering industrial growth in the interior region were phased out. Instead, privileges were granted to the coastal areas. Such a change was inevitable given the post-1978 efficiency/profit-oriented development goal and decentralized administrative institutions. As the efficiency of static resource utilization of the coastal areas was still significantly higher than the interior areas, the enhancement of static efficiency required the transfer of resources from the interior to the coastal areas. In addition, the open-door policy could be more effectively implemented by the coastal areas due to geographical proximity and a superior investment environment. Thus, in the short run, to attract foreign investment, preferential policies were to be granted to the coastal areas. Finally, devolution of decision-making and management over the use of funds and resources to local authorities and enterprises facilitated inter-regional resource movements. As productivity was higher in the East, profit-seeking practices resulted in the outflow of resources from the interior to the coastal areas. In fact, with the decrease of direct control over resources and funds, the central authority found it increasingly difficult to realize the planned delivery of resources to the interior areas. Thus, starting in 1979, the pattern of spatial resource allocation was reversed. Nevertheless, it was not until 1985 that the central authority did officially proclaim the practice of a three-tier gradated regional development strategy during the Seventh Five-Year Plan (1986-1990).[5]

The underlying rationale of the development strategy is the law of comparative advantage. China has been divided into three economic regions: the East, the Middle and the West. The East would serve as the growth pole specializing in the production of relatively technology-intensive products especially for exports. An outward-oriented development strategy would be implemented. To attract foreign investment, promote exports and foster the development of high-tech industries, preferential policies, tax concessions and administrative autonomy would be granted to the East. The other two regions should cooperate with and help the East achieve the above objectives. In return, the East should cut back production of some low-tech products such as low-priced mass consumption goods, leaving the market to other regions. Areas within the middle region are relatively well-endowed with mineral ores and natural resources. They should concentrate on producing industrial raw materials, energy and selected manufacturing industries in which they enjoy endowment advantages. It is believed that although the middle and the western regions may have to sacrifice some autonomy and economic growth rate at the initial stage, the strategy would enhance the economic growth of the "high-productivity" region very substantially. In the second phase, via the powerful linkage and multiplier effects generated by the growth poles in the East, the growth momentum would be transmitted to the interior regions step by step in accordance with productivity differentials and the law of comparative advantage, i.e., the Middle first, followed by the West. Thus, what had happened in the East during the early stage would occur in the Middle and then in the West. Initial income and productivity disparities would be contained and reduced while the whole nation would enjoy much more rapid growth.

The gradated regional development strategy constituted a very important component of the Seventh Five-Year Plan. At present, it is still advocated by many officials and researchers. The Seventh Five-Year Plan is all history now. It is time to give some preliminary assessment of the three-tier gradated regional development strategy. This chapter attempts to examine the regional disparities of sectoral labour productivities between 1985 and 1989. The analysis focuses on five sectors: industry, agriculture, construction, transportation and communication, and domestic trade, which constitute the national income of China. Section II investigates the changes in regional disparities of labour productivity for various sectors to find out whether the gradated development strategy did enlarge the disparities among the East, the Middle and the West. In addition, the impact on intra-regional disparities will be examined. Section III attempts to calculate the changes in relative competitiveness of labour productivity in various sectors for each province and the three regions, i.e., the East, the Middle and the West, using the modified "Shift-Share Model" to identify the sectoral structure and relative competitiveness effect. The relative net labour productivity competitiveness for each province and region will be compiled after isolating overall productivity changes due to the shifts in the sectoral employment structure. The issue of the impact of the gradated regional development strategy on inter-regional disparities in labour productivity competitiveness will thus be clarified. Concluding remarks are given in Section IV.

II. Regional Disparities in Labour Productivity

Disparity in Per Capita National Income

In theory, the patterns of regional disparities in income and productivity change in accordance with the regional development strategy. Thus, as mentioned in the introductory section, the disparities in output share, income and productivity between the relatively advanced region, the East, and the backward regions, i.e., the Middle and the West, should have been narrowed during 1953-1978, especially in the mid-sixties. On the contrary, the disparities are expected to have widened again since 1979, especially after 1985, if the trickle-down or spread effect triggered by the privileged region (the East) were not substantial and rapid enough to off-set the backwash effect. Persistent and growing regional disparities, however, could have serious political and economic implications.

As shown in Table 1A, measured by the weighted coefficient of variation[6] of per capita national income of all provinces and the three municipalities directly under the Central Government (DUCG), i.e., Beijing, Tianjin and Shanghai, the degree of inter-provincial income disparity surged up from 0.5497 in 1953 to 0.7846 in 1978 and then declined to 0.5741 in 1985 and further to 0.4442 in 1990. Such a pattern of changes seems to be in contradiction with the conventional wisdom that discriminatory development policies in favour of (against) the relatively backward and poor region(s) at the expense of (to the benefit of) the relatively more productive and well-to-do region(s) should reduce (enlarge) regional income disparities. However, by decomposing inter-provincial disparity into intra-regional and inter-regional disparities,[7] grouping all provinces into three regions, the East, the Middle and the West, we find that the conventional wisdom still holds: preferential policies for the Middle and the West before 1979 did narrow inter-regional income disparity between the advanced and backward regions. Table 1B shows that the ratio of per capita national income in the East to that in the Middle and in the West had changed from 100 : 77.612 : 55.439 in 1953 to 100 : 82.926 : 72.775 in 1965 when the Third-Front construction drive had begun to take pace. With the waning of the war preparation campaign, the ratio changed to 100 : 68.008 : 55.240 in 1978. Then, with the gradual shift of attention from the interior areas back to the coastal areas, especially with the opening of the 14 coastal cities in 1984, the ratio changed to 100 : 66.910 : 54.167 indicating growing disparity between the coastal and interior regions. Nevertheless, in 1985, as a result of the retrenchment policies which affected foreign investment in the coastal areas, the relative (per capita) income of the Middle and the West enjoyed some improvement. After 1985, however, inter-regional disparities increased. In 1989, the average per capita income in the Middle and the West accounted for 63.824 per cent and 52.606 per cent respectively of that in the East. The decline of the Middle was spectacular. Then, once again, as a result of the full play of the retrenchment-cum-readjustment policies, the relative position of the interior regions, especially the West, improved in 1990.

Table 1A Inter-provincial and intra-regional disparities(1) in per capita national income(2), 1953-1990

Year	InPD(3)	IrRD(4)			VIrRD(5)
		E	M	W	V_T
1953	0.5497	0.6353	0.3969	0.2781	0.8808
1965	0.5960	0.7807	0.3426	0.2176	0.9509
1978	0.7846	0.8915	0.3008	0.2176	0.9000
1984	0.5888	0.5916	0.2488	0.1825	0.8055
1985	0.5741	0.4876	0.2035	0.1445	0.7924
1989	0.4835	0.4509	0.1994	0.1535	0.6850
1990	0.4442	0.4286	0.2006	0.1599	0.6929

Sources: *Statistical Yearbook of China*, various issues and Hsueh, Li and Liu (1993).

Notes: (1) The degree of disparity is measured by the weighted coefficient of variation.

(2) Per capita national income at current price.

(3) InPD is inter-provincial disparity in per capita national income

$$= \frac{1}{\overline{Y}} \sqrt{\sum_k (Y_k - \overline{Y})^2 P_k}$$

where $\overline{Y}$ is the national mean of per capita national income $= \sum_k Y_k P_k$; Y_k is the per capita national income of province k; P_k is the population share of province k.

(4) IrRD is intra-regional disparity in per capita national income

$$= \sqrt{\frac{1}{\overline{Y}_j} \sum_k (Y_{kj} - \overline{Y}_j)^2 P_{kj}}$$

where j is the pertinent region; E = East, M = Middle, W = West; $\overline{Y}_j$ is the mean of per capita national income in region j $= \sum_k Y_{kj} P_{kj}$

where Y_{kj} is per capita national income of province k in region j; P_{kj} is the population share of province k against the total of region j; the East includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi and Hainan; the Middle includes Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan; the West includes Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Ningxia, Qinghai and Xinjiang.

(5) The sum of intra-regional variations over total inter-provincial variations is

$$\frac{\sum_j \sum_k (Y_{kj} - \overline{Y}_j)^2 P_{kj}}{\sum_k (Y_k - \overline{Y})^2 P_k}$$

where the numerator is the total sum of intra-regional variations of the East, the Middle and the West.

Table 1B Inter-regional variation and comparison of per capita national income, 1953-1990

Year	InRD(1)	VInRD/V_T (2)	$Y_E : Y_M : Y_W$ (3)
1953	0.2115	0.1480	100 : 77.612 : 55.439
1965	0.1336	0.0503	100 : 82.926 : 72.775
1978	0.2389	0.0927	100 : 68.008 : 55.240
1984	0.2626	0.1990	100 : 66.910 : 54.167
1985	0.2434	0.1798	100 : 68.758 : 54.736
1989	0.2708	0.3136	100 : 63.824 : 52.606
1990	0.2451	0.3044	100 : 65.534 : 55.789

Sources: See Table 1A.

Notes: (1) Inter-regional disparity in per capita national income

$$=\frac{1}{\bar{Y}}\sqrt{\sum_j (\bar{Y}_j-\bar{Y})^2 P_j}$$

where P_j is the population share of region j; for the computation of $\bar{Y}$ and $\bar{Y}_j$, see Table 1A.

(2) Proportion of inter-regional variation against total inter-provincial variation in per capita national income

$$=\frac{\sum_j (\bar{Y}_j-\bar{Y})^2 P_j}{\sum_k (Y_k-\bar{Y})^2 P_k}.$$

(3) The ratio of per capita national income of the East to that of the Middle and of the West.

As a matter of fact, the upsurge of inter-provincial income disparity during 1953-1978 had primarily been due to the increase of intra-regional income disparity in the East as indicated by the abrupt rise of the weighted coefficient of variation in the per capita income of all provinces in the East. During the same period, however, inter-provincial income disparities in the Middle and the West had declined. Such a pattern of changes reveals the nature of the Soviet-type development and investment policies.

Before 1978, investment had been nearly completely determined by the state. Relatively more resources had been directed to the interior regions (especially the relatively backward provinces), so inter-regional disparities between the coastal and the interior regions had decreased while intra-regional disparities in the Middle and the West had diminished. On the other hand, with the relative decrease in supplies of investable resources in the East, in order to preserve overall productivity and guarantee material supplies, resources had had to be concentrated for use in the relatively more productive provinces and municipalities (DUCG), i.e., the traditional industrial centres in the East, resulting in growing intra-regional income disparities. During 1985-1990, however, the pattern was reversed: intra-regional disparities declined substantially in the East, but surged in the Middle and the West (although not significantly). The remarkable decrease of intra-regional disparity in the East was due to a drastic diminution of relative income in the old industrial centres especially Shanghai, Beijing and Tianjin, which was, in turn, the result of the devolution of investment autonomy by the central government, diseconomies of agglomeration of economic activities in the old centres as well as the granting of preferential policies to the outward-oriented coastal provinces. In contrast, with the waning of support and subsidies to Third-line industries, the relative performance of the backward provinces in the interior region deteriorated while that of the advanced provinces improved. Nevertheless, during the early stage of economic liberalization (1979-1984), intra-regional inequalities in all regions: the East, the Middle and the West declined. It might be attributable to the diminution of intra-regional policy differences and the increase of autonomy for all authorities to arrange their activities on a competitive basis. These effects were, however, once and for all. All in all, after 1978, with the net decrease of intra-regional disparities and increase of inter-regional inequalities, the percentage share of inter-regional variation in total inter-provincial variation surged from 9.27 per cent in 1978 to 31.36 per cent in 1989 in contrast with the decrease from 14.80 per cent in 1953 to 5.03 per cent in 1965 (see Table 1B).

Labour Productivity Disparities

Concerning labour productivity disparities, we focus on the changes which took place in the five sectors: agriculture, industry, construction, transportation and communication, and domestic trade during 1985-1989. Owing to data inadequacy, and the lack of provincial capital stock data for each of the five sectors, we cannot apply the production function approach to estimate marginal labour productivity. In addition, the practice that averages labour productivity still remains one of the most important efficiency indicators for performance assessment in China; as well, with the close linkage between per capita income and average labour productivity, we use average labour productivity rather than marginal productivity for analysis. Tables 2, 3, 4 and 5 summarize for each region the output composition and employment structure, the output share and employment share (relative to the national total) of each of the five sectors in 1985 and 1989. Figures of the average labour productivity for each sector in 1985 and 1989 are presented in Tables 6 and 7 respectively.

Table 2 Output composition and employment structure of national income by region and by sector, 1985 (%)

Region	Ag	I	Cn	Tr	D_T	Cn+Tr+D_T
East	20.909[(1)]	59.226	5.783	4.102	9.998	19.865
	(55.609)[(2)]	(21.149)	(4.698-4.956)	(2.532-2.791)	(15.495-15.754)	(23.242)
	<0.8907>[(3)]	<1.2566>	<1.1560-1.1867>	<1.0739-1.1305>	<1.0992-1.1088>	<1.1208>
Middle	33.890	46.160	6.832	4.752	8.364	19.948
	(64.213)	(15.619)	(3.749)	(2.456)	(13.963)	(20.168)
	<1.0285>	<0.9280>	<0.8955-0.9222>	<0.9948-1.0416>	<0.9826-0.9905>	<0.9726>
West	34.580	42.485	8.004	4.101	10.830	22.935
	(72.57)	(10.542)	(3.348)	(1.886)	(11.679)	(16.913)
	<1.1624>	<0.6264>	<0.8017-0.8236>	<0.7639-0.7999>	<0.8220-0.8285>	<0.8156>
National	26.997	52.630	6.451	4.299	9.624	20.374
	(62.433)	(16.831)	(4.0653-4.1764)	(2.358-2.469)	(14.097-14.208)	(20.737)

Sources: See Table 1A.

Notes: Sectors: Ag = Agriculture; I = Industry; Cn = Construction; Tr = Transportation and Communication; D_T = Domestic Trade.

Regions: As listed in the notes of Table 1A, Hainan is not included in the East and Tibet is excluded from the West due to paucity of data. As no data on employment in the construction sector of Hainan are available and the data available for employment in Guangdong include Hainan's, so we have to estimate based on available data concerning total employment as well as the employment level in Agriculture and Industry in Hainan. Data on employment share of the East and of the whole nation of the table on Cn, Tr, and D_T are based on estimates of the lower and upper limits of employment in the construction sector in Hainan. For instance, the 4.698 per cent on employment share of the construction sector in the East is derived based on the assumption that all employment in Hainan other than Agriculture and Industry is absorbed by the construction sector. Then, the corresponding estimated employment share of Tr and D_T in the East should be 2.791 per cent and 15.754 per cent respectively. The 4.956 per cent on the other hand is arrived at by assuming that employment in the construction sector of Hainan is zero.

(1) Figures without parentheses: output share of the pertinent sector in national income of the region concerned.

(2) Figures with ( ): employment share of the pertinent sector in national total employment of the region concerned.

(3) Figures with < >: employment share of the pertinent sector in the relevant region/employment share of the same sector in national total employment, which may be regarded as the revealed comparative advantage of the pertinent sector for the region in question.

Table 3 Output composition and employment structure of national income by region and by sector, 1989 (%)

Region	Ag	I	Cn	Tr	D_T	Cn+Tr+D_T
East	16.872[1]	63.928	4.944	4.497	9.759	19.200
	(52.040)[2]	(22.127)	(5.389)	(3.012)	(17.432)	(25.833)
	<0.8666>[3]	<1.2732>	<1.2162>	<1.1636>	<1.1212>	<1.4470>
Middle	27.731	52.822	5.652	5.083	8.713	19.448
	(62.262)	(16.021)	(3.920)	(2.537)	(15.260)	(21.717)
	<1.0368>	<0.9219>	<0.8846>	<0.9800>	<0.9816>	<0.9623>
West	21.964	46.565	7.1145	4.794	12.348	24.254
	(71.369)	(10.749)	(3.442)	(1.960)	(12.545)	(17.882)
	<1.1884>	<0.6185>	<0.7767>	<0.7323>	<0.8069>	<0.7924>
National	21.964	57.974	5.490	4.714	9.858	20.062
	(60.054)	(17.379)	(4.431)	(2.589)	(15.547)	(22.567)

Sources: As for Table 1A.

Notes: (1), (2), (3): The same as in Table 2 except that data on Hainan's employment structure are available so employment shares of the East on Cn, Tr, D_T are actual data rather than estimates as in Table 2.

Table 4 Output share and employment share in national total by region, 1985 (%)

Region	NI[1]	Ag	I	Cn	Tr	D_T	Cn+Tr+D_T
East	53.936[2]	41.773	60.696	48.356	51.460	55.936	52.590
	(43.031)[3]	(38.328)	(54.069)	(49.729-51.067)	(46.217-48.638)	(47.299-47.711)	(48.230)
Middle	30.339	38.086	26.611	32.132	33.54	26.368	29.705
	(33.972)	(34.940)	(31.526)	(30.499-31.332)	(33.784-35.387)	(33.385-33.650)	(33.041)
West	15.725	20.141	12.694	19.512	15.000	17.696	17.702
	(22.998)	(26.732)	(14.405)	(18.435-18.939)	(17.568-18.396)	(18.904-19.053)	(18.729)

Sources: As for Table 1A.

Notes: (1) National income = aggregation of all five sectors.

(2) Figures without parentheses: proportion of the output value (in constant price) of the pertinent sector of the concerned region in national output value of the same sector.

(3) Figures with parentheses: proportion of the employment level of the pertinent sector of the concerned region in national employment level of the same sector.

Table 5 Output share and employment share in national total by region, 1989 (%)

Region	NI[1]	Ag	I	Cn	Tr	D_T	Cn+Tr+D_T
East	55.194[2]	42.498	60.862	49.709	52.649	54.639	52.822
	(42.392)[3]	(36.734)	(53.973)	(51.557)	(49.325)	(47.531)	(48.527)
Middle	29.180	36.841	26.587	30.041	31.460	25.791	28.286
	(34.269)	(35.529)	(31.592)	(30.315)	(33.584)	(33.637)	(32.978)
West	15.626	20.761	12.551	20.251	15.891	19.570	18.892
	(23.339)	(27.737)	(14.435)	(18.128)	(17.091)	(18.833)	(18.495)

Sources: As for Table 1A.

Notes: (1), (2), (3): The same as in Table 4.

Table 6 Average labour productivity[1] by sector and by region, 1985 (RMB)

Region	NI	Ag	I	Cn	Tr	D_T	Cn+Tr+D_T
East	1462.49	549.90	4095.66	1706.48-1800.27	2149.64-2368.87	926.54-941.98	1250.00
		<0.3760>[2]	<2.8005>	<1.2310-2.2778>	<1.4699-1.6198>	<0.6335-0.6441>	<0.8547>
	(1.2530)[3]	(1.0899)	(1.1226)	(0.9469-0.9724)	(1.0581-1.1135)	(1.1724-1.1826)	(1.0904)
Middle	1042.03	549.97	3079.70	1898.66	2016.03	624.19	1030.60
		<0.5278>	<2.9555>	<1.8221>	<1.9347>	<0.5990>	<0.9890>
	(0.8931)	(1.090)	(0.8441)	(1.0255-1.0536)	(0.9477-0.9923)	(0.7838-0.7900)	(0.8988)
West	797.80	380.15	3215.17	1907.41	1734.76	739.80	1083.45
		<0.4765>	<4.0301>	<2.3909>	<2.1744>	<0.9273>	<1.3581>
	(0.6838)	(0.7535)	(0.8812)	(1.0303-1.0584)	(0.8155-0.8539)	(0.9285-0.9358)	(0.9452)
National	1166.79	504.55	3648.54	1802.13-1851.39	2031.60-2127.34	790.30-796.53	1146.32
		<0.4324>	<3.1270>	<1.5445-1.5867>	<1.7412-1.8232>	<0.6773-0.6827>	<0.9825>

Table 6 (Continued)

East[4]	1 :	1 :	1 :	1 :	1 :	1 :	1 :
Middle	0.7125 :	1.000 :	0.7519 :	1.0547-1.1130 :	0.8511-0.9378 :	0.6626-0.6737 :	0.8245 :
West	0.5455	0.6913	0.7850	1.0595-1.1177	0.7323-0.8070	0.7854-0.7985	0.8668

Sources: As for Table 1A.

Notes:
(1) Average labour productivity of a region is the weighted average of the average labour productivity of all provinces within their jurisdiction; the weight is the employment share of the pertinent province in regional total. It is the net value output per labour in constant price expressed as RMB.

(2) Figures with < >: average labour productivity of the pertinent sector as a proportion of per labour national income of the region to which it belongs.

(3) Figures with ( ): average labour productivity of the pertinent sector of the concerned region as a proportion of the national average of the same sector.

(4) The ratio of average labour productivity of the pertinent sector in the East to that in the Middle and in the West.

Table 7 Average labour productivity by sector and by region, 1989 (RMB)

Region	NI	Ag	I	Cn	Tr	D_T	Cn+Tr+D_T
East	1864.924	604.627	5388.016	1710.955	2784.211	1044.049	1386.079
		<0.3242>	<2.8891>	<0.9174>	<1.4929>	<0.5598>	<0.7432>
	(1.3020)	(1.1542)	(1.1276)	(0.9641)	(1.0674)	(1.1496)	(1.0885)
Middle	1219.634	543.205	4021.49	1758.568	2443.402	696.385	1092.197
		<0.4454>	<3.2970>	<1.4419>	<2.0034>	<0.5710>	<0.8955>
	(0.8515)	(1.0369)	(0.8416)	(0.9910)	(0.9367)	(0.7668)	(0.8577)
West	958.997	392.113	4154.407	1982.357	2425.284	943.788	1300.730
		<0.4089>	<4.3320>	<2.0671>	<2.5290>	<0.9841>	<1.3563>
	(0.6695)	(0.7485)	(0.8695)	(1.1171)	(0.9298)	(1.0392)	(1.0215)
National	1432.351	523.860	4778.126	1774.588	2608.409	908.225	1273.377
		<0.3657>	<3.3359>	<1.2389>	<1.8211>	<0.6341>	<0.8890>
East	1 :	1 :	1 :	1 :	1 :	1 :	1 :
Middle	0.6540 :	0.8984 :	0.7463 :	1.0278 :	0.8776 :	0.6670 :	0.7880 :
West	0.5142	0.6485	0.7711	1.1586	0.8711	0.9040	0.9384

Sources: As for Table 1A.

Notes: The same as in Table 6.

As shown in Tables 2 and 3, compared with the Middle and the West, the employment structures of the East in 1985 and 1989 are biased in favour of the non-agricultural activities, especially of industrial production. The ratio of the percentage share of agricultural employment (to total employment) in the East to that of the national total is smaller than 0.9 while the same ratios for the Middle and the West are larger than 1. The corresponding ratios for non-agricultural sectors in the East are all larger than 1 with a maximum of 1.257 and 1.273 for industrial output in 1985 and 1989 respectively. Conversely, the ratios for all non-agricultural production in the Middle and in the West are smaller than 1. Nevertheless, even in the East, the agricultural sector still absorbs more than 50 per cent of total employment although the agricultural output only accounts for about 20 per cent of national income. On the other hand, the industrial sector, with less than 25 per cent of total labour force, generates over 50 per cent of national income. It implies a substantial disparity in labour productivity between the agricultural and industrial sectors. Similarly significant disparities occur in the Middle and in the West as well (see Tables 6 and 7). As a matter of fact, on average, the average labour productivity of the (most productive) industrial sector is 5-10 times that of the (least productive) agricultural sector. The weighted coefficients of variation in average labour productivity of the five sectors for all provinces in the East, the Middle and the West are 0.9024, 0.898 and 1.127 respectively in 1985, which increase to 1.0174, 1.0578 and 1.2755 in 1989. The weighted average of the coefficients of variation for the three regions combined are 0.9525 in 1985 and 1.0915 in 1989. Thus, the intra-regional-inter-sectoral labour productivity disparities are large and surging upwards during 1985-1989. It is to be noted that the disparity is the largest in the least productive region, the West, implying a more severe dualistic economic structure with less spread effect transmitted from the most productive sector. Moreover, labour productivity of the industrial sector experiences the most rapid growth although it is already the highest among the five sectors, thus widening inter-sectoral disparities. Unfortunately, by 1985, on average, at the national level more than 60 per cent of the labour force is still employed in the least productive (agricultural) sector while the most productive (industrial) sector absorbs less than 17 per cent of labour. Obviously, the employment structure of China, especially the Middle and the West is not conducive to labour productivity growth. Reallocation of labour from agricultural to non-agricultural sectors especially the industrial sector could improve the overall labour productivity substantially if essential material inputs are available.

With regard to the inter-regional-intra-sectoral labour productivity differences, as shown in Tables 6 and 7, in general, the East performs best except for construction and agricultural production. On balance, overall average labour productivity in the East is higher than that in the Middle and the West. The disparities grow larger in 1989. The ratios of overall average labour productivity in the East to that in the Middle and in the West is 100 : 71.25 : 54.55 in 1985, changing to 100 : 65.40 : 51.42 in 1989. Relatively higher productivity in the East can be attributable to better factor supply conditions, (especially those concerning the supply of human capital, general infrastructure and productive assets) as well as preferential policies for the attraction of foreign investment. The growing inter-regional disparity in overall labour productivity coincides with widening inter-regional inequality in per capita national income.

To test whether inter-regional-intra-sectoral disparities have been enlarged or reduced during 1985-1989, the weighted coefficient of variation of average labour productivity for each sector of all provinces and municipalities (DUCG) in 1985 and 1989 is compiled. Similar to the above analysis of income disparities, variations of labour productivity are decomposed into intra-regional and inter-regional variations (see Table 8). The exercise indicates that in 1989, the inter-provincial productivity disparity for the five sectors combined is practically the same as that in 1985, changing from 0.60777 to 0.60791. The productivity disparity in industrial production declines while the ones for agriculture, construction, transportation and communication, and domestic trade production go up during the same period. Nevertheless, the intra-regional and inter-regional decomposition indicates an increase in the share of inter-regional variation in total (inter-provincial) variations for all sectors combined, and for agricultural and industrial production. Notably, the share of inter-regional variations in industrial production surges from 13.535 per cent to 20.718 per cent while that of all sectors combined increases from 14.760 per cent to 19.405 per cent. All in all, for national income, agricultural production and industrial production, labour productivity disparities between the East, the Middle and the West widens in 1989. The West, however, shows some noticeable improvement relative to the East in construction, transportation and communication, and domestic trade. The largest loser in the labour productivity race is the Middle.

From intra-regional analysis, it is found that in 1989, intra-regional disparities in the East for all five sectors combined are substantially larger than that of the Middle and of the West. The respective weighted coefficients of variation are 0.61506, 0.28774 and 0.22862 (see Table 9). Similar results hold for agriculture, industry, transportation and communication, and domestic trade. Productivity disparity in the construction sector of the East is slightly smaller than that of the Middle but larger than that of the West. For inter-temporal comparison (between 1985 and 1989), intra-regional disparities in all five sectors combined decline in the East (from 0.6842 to 0.6151); the most abrupt decline is in the West (from 0.4974 to 0.2286). The Middle, however, sees an increase from 0.2878 to 0.3118. For agriculture, inter-provincial disparity in the whole nation increases although it declines in the Middle. Disparities in industrial labour productivity decline notably in the East and slightly in the Middle, while they remain practically unchanged in the West. The positive correlation between the size of intra-regional disparities and the regional productivity level on cross-sectional basis implies the tendency for disparities to increase when income and general productivity (particularly for a relatively less-developed region) grow beyond some critical levels under an economic environment and develop-

Table 8 Intra-regional and inter-regional variations[1] of average labour productivity by sector, 1985 and 1989

		NI	Ag	I	Cn	Tr	D_T
1985	V_T	502872.11	24350.27	1752241.01	171037.77	773960.69	199257.95
		<0.60777>[2]	<0.30928>	<0.36281>	<0.22949>	<0.41355>	<0.56041>
1985	V_a	428644.86	18697.02	1508654.40	161480.61	717850.29	178643.09
		(0.85240)[3]	(0.76784)	(0.86099)	(0.94410)	(0.92750)	(0.89654)
1985	V_r	74226.10	5645.83	237158.37	9557.13	59697.74	20614.58
		(0.14760)	(0.23186)	(0.13535)	(0.05588)	(0.07133)	(0.10346)
1989	V_T	758194.70	30653.60	2113823.20	467711.95	1213700.50	287789.40
		<0.60791>	<0.33420>	<0.30428>	<0.38538>	<0.42236>	<0.59067>
1989	V_a	611002.30	23309.95	1675882.15	457721.00	112381.09	263687.80
		(0.80586)	(0.76043)	(0.79282)	(0.97864)	(0.92571)	(0.91625)
1989	V_r	147124.20	7343.60	437943.00	9990.92	30119.99	24101.60
		(0.19405)	(0.23957)	(0.20718)	(0.02136)	(0.02482)	(0.08374)

Sources: As for Table 1A.

Notes: (1) The total inter-provincial-intra-sectoral variation in labour productivity is the weighted sum of squares of the deviation of provincial average labour productivity in the pertinent sector from the national mean of the same sector:

$$V_T = \sum_k (X_{ik} - \overline{X}_i)^2 \, l_{ik}$$

which can be decomposed into intra-regional variation:

$$V_a = \sum_j \sum_k (X_{ik} - \overline{X}_{ij})^2 \, l_{ikj}$$

and inter-regional variation:

$$V_r = \sum_j (\overline{X}_{ij} - \overline{X}_i)^2 \, l_{ij}$$

For definitions of the variables and rationale of the method, see Note 7.

(2) Weighted coefficient of variation of average labour productivity among all provinces; for a definition of weighted coefficient of variation see notes of Table 1A.

(3) Figures in parentheses indicate the proportion of the size of the pertinent type of variation in total variations. Note that the cross terms as indicated in Note 7 are not shown in the table. Nevertheless, for all sectors except transportation and communication the cross terms approach zero. The cross term however accounts for 4.9 per cent of total variations in labour productivity of transportation and communication in 1989.

ment strategy similar to those during 1985-1989, if the weighted coefficient of variation is employed to measure the degree of disparity.[8]

Table 9 Analysis of intra-regional disparities[(1)] in labour productivity by sector, 1985, 1989

	DNI[(1)]	DAG[(1)]	DI[(1)]	DC[(1)]	DTr[(1)]	DD_T[(1)]
East	0.61506[(2)]	0.49560	0.31507	0.41259	0.44522	0.66233
	(0.68417)[(3)]	(0.21855)	(0.39730)	(0.29157)	(0.47418)	(0.62620)
Middle	0.28774	0.26248	0.13512	0.42345	0.29637	0.20078
	(0.31177)	(0.31547)	(0.14328)	(0.14744)	(0.16718)	(0.27919)
West	0.22682	0.34646	0.10450	0.21423	0.43419	0.42170
	(0.49736)	(0.26160)	(0.10252)	(0.12901)	(0.41317)	(0.19220)

Sources: As for Table 1A.

Notes: (1) The degree of disparity is measured by the weighted coefficient of variation in average labour productivity of the pertinent sector among all provinces within the concerned region.
For instance, DNI in the table is the weighted coefficient of variation in average labour productivity of all five sectors combined. For definition of weighted coefficient of variation see notes of Table 1A.

(2) Figures without parentheses refer to the weighted coefficient of variation for the pertinent sector in 1989.

(3) Figures with parentheses are coefficients of variations for 1985.

It is to be noted that the inter-regional-intra-sectoral productivity disparities (on the five-sector basis) are small relative to intra-regional-inter-sectoral disparities. In 1989, the domestic trade sector experiences the largest inter-provincial productivity disparity with a weighted coefficient of variation of 0.59067 which is, however, only moderately larger than the smallest inter-sectoral disparity (0.5249) achieved by Shanghai among all provinces and municipalities (DUCG). In 1989, the weighted average for inter-provincial productivity disparities of the five sectors in the

East, the Middle and the West are only 0.36954, 0.23983 and 0.327 respectively. As a matter of fact, the relatively low overall labour productivity in the West is partly due to its non-growth-conducive output structure. Over 70 per cent of its labour force is employed in the least productive sector, agriculture, with average labour productivity equivalent to about 10 per cent of the most productive sector, industry. It can be shown that were the West to adopt the average employment structure of the whole nation in 1985, its overall average labour productivity would rise by 25.764 per cent.[9] In case the employment structure of the East is adopted, the rate of increase can be as high as 43.453 per cent. It is to be noted that, as verified in the next section, even the employment structure in the East is not conducive to overall labour productivity growth. Thus, the whole nation (and the West in particular) does have huge potentials for enhancing general labour productivity via a reshuffling of the employment structure in favour of the more productive sectors. During the course of reshuffling, as the spread effect is still not substantial at the early stage — due to the fragmented dualistic nature of the economic structure — inter-sectoral inequalities rise, with implication for income distribution. With the strengthening of the spread effect as a result of the spreading inter-sectoral integration of the economic system (symbolized by a higher level of per capita productivity and income) the disparity ultimately becomes smaller.

Generally, the inter-sectoral productivity disparities are relatively smaller in the provinces and municipalities (DUCG) with higher productivity (see Table 10). The most notable examples are Shanghai and Tianjin which attain the highest average labour productivity but the least inter-sectoral productivity disparities in both 1985 and 1989. On the other hand, the least productive provinces, Guizhou and Guangxi, experience large inter-sectoral productivity disparities: the highest in 1985 and among the top three in 1989. Furthermore, inter-sectoral productivity disparities of all three regions surge during 1985-1989. Spectacular increases occur in the Middle which overtake the East to rank second, following the West. The upsurge of inter-sectoral disparities is due to a relatively more rapid growth of labour productivity in relatively more productive sectors such as 'industry, transportation and communication; but productivity growth in agricultural production, the least productive activity, remains stagnant. The growth rates of the average labour productivity of these sectors in 1989 over 1985 are 30.97 per cent, 22.6 per cent, 28.4 per cent and 3.74 per cent respectively compared with 22.83 per cent for the overall growth rate of national income. In addition, the reshuffling of the employment structure in favour of industrial and other non-agricultural production activities at the expense of the agricultural sector accelerates the widening of inter-sectoral disparities (measured by the weighted coefficient of variation). In general, the employment share of agriculture declines from 62.472 per cent in 1985 to 60.05 per cent in 1989. The largest decrease happens in the East, a decrease of total employment by 3.57 percentage points. All other non-agricultural sectors do experience some increase in employment as well.

Table 10 Inter-sectoral disparity in labour productivity by province and by region, 1985

	NI[1]	Ag[2]	I[2]	Cn[2]	Tr[2]	D_T[2]	InSD[3]
Beijing	2947.33	0.4077	1.9230	1.2117	0.9875	0.3062	0.7278
Tianjin	2954.38	0.2723	1.6237	0.7687	1.5580	0.3055	0.6438
Hebei	1091.87	0.4831	3.0246	0.0964	1.7717	0.8541	0.9229
Liaoning	1975.04	0.3219	2.0983	0.8821	1.7264	0.4033	0.8182
Shanghai	5733.91	0.1596	1.5645	0.3379	0.8095	0.5613	0.5898
Jiangsu	1441.21	0.4265	2.4375	1.1121	0.9507	0.4357	0.8644
Zhejiang	1194.47	0.4575	2.2530	1.5193	1.5693	0.7277	0.7574
Fujian	1090.04	0.5077	3.0951	1.5214	1.7229	0.7161	0.9073
Shandong	1077.04	0.5446	3.2095	1.4283	1.4401	0.5791	0.9432
Guangdong	1239.13	0.4505	3.0228	1.4129-2.1947	1.3054-3.3451	0.7695-0.8609	0.9373-0.9471
Guangxi	595.23	0.5081	5.2003	2.4850	2.2943	1.5783	1.2189

Table 10 (Continued)

East	1462.49	0.3760	2.8005	1.2310-1.1668	1.4699-1.6199	0.6335-0.6441	0.9654-0.9658
							<0.9023>[3]
Shanxi	1166.59	0.4230	2.3653	1.7744	1.8489	0.3594	0.8585
Inner Mongolia	1066.88	0.6641	2.1192	2.3714	2.1673	0.5281	0.6583
Jilin	1416.65	0.6126	2.0149	1.5990	1.3654	0.3563	0.6651
Heilongjiang	1807.59	0.5948	2.0220	1.1950	1.4751	0.2142	0.7115
Anhui	850.42	0.6028	3.4656	1.7957	1.9322	0.5860	0.9385
Jiangxi	895.63	0.5798	2.8834	2.3399	2.0727	0.5689	0.8568
Henan	822.07	0.5112	3.5954	2.0358	2.6152	1.0027	1.0047
Hubei	1312.58	0.5480	2.8090	1.3884	1.1604	0.6250	0.8470
Hunan	808.97	0.5191	3.8035	2.0807	2.5190	0.9689	1.0455
Middle	1042.03	0.5278	2.9555	1.8221	1.9347	0.5990	0.8998
							<0.8979>
Sichuan	776.39	0.4939	4.1089	2.3007	1.8149	0.9873	1.1265
Guizhou	604.64	0.4761	5.1433	3.4613	3.5070	0.9928	1.3377
Yunnan	681.68	0.5140	4.9741	2.6726	1.5828	1.3005	1.1961
Shaanxi	870.14	0.3950	3.1800	3.7994	2.2662	0.7778	1.1797
Gansu	917.63	0.3805	3.1851	2.6683	1.3971	0.9099	0.9334
Qinghai	1008.54	0.4546	2.8980	2.4278	1.2712	0.8279	0.8965
Ningxia	1080.30	0.4377	2.8126	2.6136	2.2846	1.1155	0.9004
Xinjiang	1270.44	0.6438	2.9613	1.7045	1.2635	0.6721	0.7556
West	797.80	0.4765	4.0301	2.3909	2.1744	0.9273	1.1228
							<1.1270>[4]
National	1166.79	0.4324	3.1270	1.5445-1.5867	1.7412-1.8232	0.6773-0.6827	1.0026-1.0037
							<0.9525>[4]

Sources: As for Table 1A.

Notes: (1) NI is per labour national income in constant price.

(2) Figures for Ag, I, Cn, Tr, D_T are proportion of per-labour net output value of the pertinent sector of the concerned province (region) against per-labour national income of the same province (region).

(3) InSD is inter-sectoral disparity in average labour productivity of the province (region), computed as follows:

$$InSD_k = \frac{1}{\overline{Y}_k}\sqrt{\sum_i (Y_{ik} - \overline{Y}_k)^2\, l_{ik}}$$

where $InSD_k$ is inter-sectoral disparity in province k; $\overline{Y}_k$ is per-labour national income of k; Y_{ik} is average labour productivity of sector i in province k; l_{ik} is the employment share of i in total employment of k.

(4) For regional inter-sectoral disparity, figures without parentheses are compiled as the weighted coefficient of variation of average labour productivity of the five sectors on regional basis; that is

$$InSD_j = \frac{1}{\overline{Y}_j}\sqrt{\sum_i (Y_{ij} - \overline{Y}_j)^2\, l_{ij}}$$

similar to $InSD_k$, except that regional data are used instead of the provincial data. Figures with < > are compiled as the weighted average of the inter-sectoral disparities of all provinces within the region concerned

$$= \sum_k InSD_k \cdot l_{kj}$$

where l_{kj} is the employment share of province k in regional total employment. Figure within parenthesis for national total is the weighted average of regional disparities

$$= \sum_j InSD_j \cdot l_{jn}$$

where l_{jn} is the employment share of region j in national total.

Large and growing inter-sectoral productivity disparities tempt the local authorities to alter their output and employment structures in favour of the more productive (profitable) sectors rather than to improve productive efficiency. However, subject to huge intra-regional-inter-sectoral productivity differences, without deliberate state policies, the law of comparative advantage is

not followed to arrange the pattern of economic activities at the national level. Table 11 shows the degree of comparative advantage for each sector in the region, measured by the ratio of labour productivity in the concerned sector of the pertinent region to that of the national average. Interestingly, some highly-industrialized provinces do have the largest comparative advantage in agricultural rather than industrial production. In fact, in 1989, the East has the largest comparative advantage in agricultural production. Its average agricultural labour productivity is 1.1542 times that of the national average. The corresponding ratio for industrial production is only 1.1276, although its industrial labour productivity is RMB 5,388.02, 8.9 times that of agricultural productivity. Among all provinces in the East, only Guangxi (the least productive) has the largest comparative advantage in industrial production. Assessed by the same ratio, the largest comparative disadvantage of the East is in construction. On the other hand, the West has the largest comparative disadvantage in agricultural production but the largest comparative advantage in construction. Yet, given the prevailing price structure and without state subsidies, no province/municipality (DUCG) in the East is willing to specialize in agricultural production according to the law of comparative advantage if it aims to maximize overall labour productivity because (in absolute size) its industrial labour productivity is much higher than agricultural productivity.

Table 11 Labour productivity comparative advantage[1] on provincial and regional basis, 1989

	NI	Ag	I	Cn	Tr	D_T	$Y_{CA}/Ym^{(2)}$
Beijing	2.4386	3.1103	1.4580	2.3504	1.5554	0.9390	Ag/I=0.2339
Tianjin	2.4790	2.2885	1.2078	1.4284	2.0615	1.8482	Ag/I=0.2079
Hebei	0.9228	1.0007	0.8762	0.4958	0.9071	1.2615	D_T/I=0.2444
Liaoning	1.7457	1.4904	1.0769	1.1627	1.8404	0.8897	Tr/I=0.9330
Shanghai	5.0726	2.5292	2.2597	1.6709	2.3171	4.3637	D_T/I=0.3671
Jiangsu	1.3290	1.2668	0.9954	0.8489	1.4006	0.9818	Tr/I=0.7682
Zhejiang	1.0932	1.0421	0.8428	1.1260	1.1122	1.0288	Cn/I=0.4962
Fujian	1.0156	1.2770	1.1283	0.6010	0.7342	0.7705	Ag/I=0.1241
Shandong	1.0381	1.1476	1.0704	0.8237	0.8214	0.9329	Ag/I=0.1176
Guangdong	1.2079	1.3689	1.1566	1.0352	0.9018	0.9189	Ag/I=0.1298
Guangxi	0.4857	0.6258	0.8421	0.6301	0.6249	0.8330	I/I=1
East	1.3020	1.1542	1.1276	0.9641	1.0674	1.1496	Ag/I=0.1122
Shanxi	0.8923	0.8880	0.7125	0.9380	0.6005	0.5278	Cn/I=0.4889
Inner Mongolia	0.8791	1.3845	0.6335	1.3608	1.1560	0.6871	Ag/I=0.2396
Jilin	1.0870	1.3575	0.7867	0.9204	1.2351	0.7100	Ag/I=0.1892
Heilong-jiang	1.5472	1.8406	0.9432	2.1296	1.3919	0.7144	Cn/I=0.8386
Anhui	0.6902	0.9418	0.8788	0.6379	0.6089	0.5585	Ag/I=0.1175
Jiangxi	0.7810	0.9925	0.7490	1.4030	1.2021	0.8119	Cn/I=0.6956
Henan	0.6983	0.8626	0.7932	0.7566	0.9761	0.9958	D_T/I=0.2386
Hubei	1.0458	1.3578	1.0469	0.8853	0.6440	0.7684	Ag/I=0.1422
Hunan	0.6523	0.7984	0.8234	0.7918	1.0419	0.8990	Tr/I=0.6908
Middle	0.8515	1.0369	0.8416	0.9910	0.9367	0.7668	Ag/I=0.1351
Sichuan	0.6212	0.7307	0.8260	0.9751	0.5931	0.9619	Cn/I=0.4385
Guizhou	0.4688	0.5233	0.7697	1.1903	1.0970	0.7352	Cn/I=0.5743
Yunnan	0.6165	0.6815	1.1146	1.4964	0.5887	1.3888	Cn/I=0.4986
Shaanxi	0.7439	0.7410	0.8773	0.8485	1.2670	0.3362	Tr/I=0.7885

Table 11 (Continued)

Gansu	0.8617	0.6911	0.8667	1.4814	1.7204	1.9141	D_T/Tr=0.3874
Qinghai	0.8344	0.9431	0.8793	1.3210	0.4665	0.9652	Cn/I=0.5580
Ningxia	0.9413	1.0544	0.8091	1.4850	1.3138	1.5814	D_T/I=0.3715
Xinjiang	1.1681	1.9587	0.9590	1.3764	1.3291	1.3504	Ag/I=0.2239
West	0.6695	0.7485	0.8695	1.1171	0.9298	1.0392	Cn/I=0.4772

Sources: As for Table 1A.

Notes: (1) The degree of labour productivity comparative advantage is revealed by making an inter-sectoral comparison of the ratio: average labour productivity of the pertinent sector in the concerned province/national average labour productivity of the same sector. According to the law of comparative advantage, disregarding other costs, the degree of comparative advantage of a sector should be positively correlated with the size of the ratio.

(2) Average labour productivity of the sector with the largest comparative advantage Y_{CA} (measured by the relative size of the above ratio) for the pertinent province (region) as a proportion of that of the most productive sector in the same province (region) Ym.

Concerning intra-regional productivity growth, in the East, the relative performance of the coastal provinces has been improved. Particularly, the achievements of Guangdong, Shandong, Fujian and Jiangsu have been spectacular. Shanghai and Liaoning, the traditional economic centres do attain some moderate improvement relative to the national average. However, their relative growth performance within the East deteriorates. Similarly, the performance of the northern provinces and municipalities (DUCG) as well as the least productive province (Guangxi) deteriorates relative to other provinces in the East. In 1989, the average labour productivity in Guangxi is less than 10 per cent of Shanghai. It is to be noted that even in 1989, with the exception of Jiangsu, the average labour productivity of all the above provinces which experience most rapid productivity improvement falls short of the average productivity level of the whole region. It implies that if such a pattern of differentiated growth continues, in the short run, intra-regional productivity disparities in the East would become smaller. Contrary to the East, in 1989, the growth performance of labour productivity in the Middle deteriorates relative to the national average. In fact, all provinces except Jiangxi suffer some decline. The most notable down-slide occurs in the so-called resource-based provinces and traditional industrial centres: Shanxi, Inner Mongolia, Jilin and Hubei. However, despite the remarkable relative decline, the average labour productivity of these provinces is still above the regional average in 1989. Thus, if such trend cannot be checked, productivity progress in the Middle should be gloomy. As for the West, the relative performance of the whole region deteriorates in 1989. Most disappointingly, the relative performance of Sichuan and Guizhou, the most populous and the poorest provinces, declines. However, Yunnan in the Southwest, Gansu, Ningxia and Xinjiang in the Northwest experience some improvement. Nevertheless, as workers in Sichuan account for over 40 per cent of those in the region, failure to check its (productivity) down-slide would probably result in further deterioration of the average performance of the whole region.

In summary, by decomposing the total variations of weighted average labour productivity for provinces and municipalities (DUCG), we find that, compared with 1985, the weighted inter-regional disparity of average labour productivity based on the three-region classification for all five sectors combined (that is, national income) does increase, although the size of the weighted inter-provincial coefficient of variation for the whole nation remains practically unchanged. In general, the East performs better than the Middle and the West. The average discrepancy appears to have been enlarged further during 1985-1989. However, with respect to construction productivity, the East does perform worse than the interior regions. Especially, in 1989, the West can improve its performance relative to the East in some sectors. Inter-regional disparities in labour productivity can be attributable to differences in resource endowment, development strategies and policies. Yet, in China inter-regional-intra-sectoral disparities have usually been smaller than intra-regional-inter-sectoral disparities. In general, the average labour productivity of industry, the most productive sector, is over five times that of agriculture, the least productive sector. Thus, inter-regional disparities in overall labour productivity should have been attributable to differences in employment structure to a certain extent. Although the employment structure of the whole nation in 1985 is not growth-conducive, that of the East performs better while the West performs the worst. Large inter-sectoral disparities have tempted local authorities to "rationalize" their employment structure, to expand the industrial and other non-agricultural sectors but to contract agricultural production. It is, however, doubtful whether the law of comparative advantage would be an important reference for determining the employment structure at the national level. Interestingly, in 1989, the East has the largest comparative advantage in agricultural production, but on average its industrial labour productivity is more than eight times that of agriculture. Thus, disregarding the supply constraint of material inputs, the objective of maximizing regional overall labour productivity would result in further specialization in industrial production, against the teaching of the law of comparative advantage. Finally, it is found that the newly-emerging outward-oriented coastal areas and those which specialize in producing processed industrial products improve their overall labour productivity faster than the traditional economic centres, especially the resource-based provinces.

III. Disparities in Relative Productivity Competitiveness

This section attempts to identify the sources of growth of average labour productivity for every province, municipalities (DUCG) and the three regions, namely, the East, the Middle and the West. The modified "Shift-Share Model"[10] is employed to decompose the realized improvement of overall labour productivity (based on the five sectors) into the constant share effect, the sectoral structure effect and the relative competitiveness effect. The ultimate objective is to calculate the relative competitiveness effect (actual productivity growth relative to that attained by the average competitiveness of the whole nation) for the three regions to see if there are significant differences in relative competitiveness between the East, the Middle and the West during 1985-1989, following the pursuit of the gradated regional development strategy in favour of the East. To estimate real relative productivity competitiveness, the impact of inter-sectoral labour reallocation on overall labour productivity changes is isolated. The degree of relative productivity competitiveness is then calculated as the proportionate deviation of realized real labour productivity changes (net of sectoral-structure change effects) from (the hypothetical) productivity changes which would have been attained by the average competitiveness of the nation. The hypothetical productivity changes in average competitiveness of the nation refers to changes that would have happened if each and every area (within the region concerned) just achieves the national average growth rate in each of the corresponding sectors within its jurisdiction over the given time period (for details concerning the model, please refer to the Appendix).

As shown in Table 12, in the East, the sectoral structure effect of the relatively highly industrialized old economic centres is positive, implying that in 1985 they allocate disproportionately large shares of labour to those sectors which have greater potential for productivity improvement. On the other hand, the sectoral structure effect for the "new comers" (with lower degree of industrialization in 1985) is negative. As a whole, the sectoral structure effect in the East is negative. Concerning gross competitiveness, the old economic centres such as Beijing, Tianjin and Shanghai experience some deterioration. The size of the negative competitiveness effect is so large for Beijing and Tianjin that they cannot uphold their relative position (in labour productivity competitiveness) of 1985 in 1989. As for Shanghai, the positive sectoral structure effect is large enough to offset the negative gross

competitiveness effect so that it can still improve its relative position (in labour productivity) in 1989. Nevertheless, Liaoning, another traditional centre, is able to improve its relative competitiveness. Concerning the "new comers," Jiangsu, Zhejiang, Fujian, Shandong and Guangdong, all achieve positive relative gross competitiveness effect which is large enough to offset the negative sectoral structure effect resulting in the improvement of their relative position in labour productivity. In both absolute and relative magnitude (relative gross competitiveness effect as a proportion of the hypothetical increase in labour productivity at national average competitiveness), Guangdong experiences the greatest improvement, followed by Shandong. Nevertheless, it is encouraging to find that the relative gross competitiveness of Hebei and Guangxi, two backward provinces, improves, although they cannot uphold their relative position of 1985 in 1989 due to the relatively large negative sectoral structure effect.

Table 12 Analysis of sources of labour productivity growth on provincial and regional bases, 1985-1989

	CS	SS	RC	Yn	RGPrC
Beijing	670.8237	21.0402	-146.2928	545.5710	-0.2114
Tianjin	672.4283	67.6968	-143.6501	596.4750	-0.1904
Hebei	248.5138	-36.7666	18.2058	229.9953	0.0860
Liaoning	449.5267	42.4542	33.4511	525.4320	0.0680
Shanghai	1305.0601	255.4259	-28.6920	1531.7940	-0.0184
Jiangsu	328.0259	-9.8696	144.2108	426.3760	0.4533
Zhejiang	217.8660	-25.7991	125.3371	371.4040	0.5094
Fujian	248.0973	-49.8245	166.3321	364.6050	0.8389
Shandong	245.1385	-48.5019	213.2774	409.9140	1.0846
Guangdong	282.0308	-47.0985	256.9352	491.0575	1.0974
Guangxi	135.4767	-40.0723	5.0967	100.5010	0.0534
East(1)	332.8684	-14.7977	84.3634	402.4340	0.2652

Table 12 (Continued)

Shanxi	265.5213	-22.9561	-131.1308	111.4344	-0.5406
Inner Mongolia	242.8260	-75.7503	25.2577	192.3334	0.1512
Jilin	322.4350	-39.5448	-142.5487	140.3315	0.5039
Heilongjiang	411.4145	-26.0780	23.2495	408.5860	0.0603
Anhui	193.5589	-51.8400	-3.5529	138.1660	-0.0251
Jiangxi	203.8489	-53.0973	72.2485	223.0000	0.4793
Henan	187.1063	-46.5429	37.6106	178.1740	0.2676
Hubei	298.7483	-51.9495	-62.1303	185.4230	-0.2510
Hunan	184.1247	-44.6436	-14.0837	125.3974	-0.1010
Middle(1)	237.1701	-46.0996	-13.4664	177.6040	-0.0705
Sichuan	176.7094	-41.9639	-21.3845	113.3610	-0.1587
Guizhou	137.6184	-35.3666	-35.4508	66.8010	-0.3467
Yunnan	155.1539	-47.1226	93.3797	201.4110	0.8644
Shaanxi	198.0472	-28.7155	26.0023	195.3340	0.1536
Gansu	208.8570	-30.8085	138.5685	316.6170	0.7783
Qinghai	229.5476	-66.8195	23.8494	186.5770	0.1466
Ningxia	245.8805	-65.3917	87.4153	267.9040	0.4843
Xinjiang	289.1571	-91.5538	205.0797	402.6830	1.0378
West(1)	181.5812	-42.6249	22.2457	160.8130	0.1601

Sources: As for Table 1A.

Notes: CS = constant share effect; SS = sectoral structure effect; RC = relative competitiveness effect; Yn = actual change in average labour productivity in the pertinent province (region) in 1989 relative to 1985; RGPrC = relative gross labour productivity competitiveness. For the calculation of these effects, see the Appendix.

(1) Mid-value estimate chosen from different estimates based on various calculations of employment figures in construction, transportation and communication, and domestic trade for Hainan in 1985. See notes in Table 2. Nevertheless, the range of the estimates is very small, less than 1 per cent.

On the whole, relative gross competitiveness in the East improves by RMB 84.3634 per labour and is sufficient to offset the negative sectoral structure effect (RMB -14.7977 per labour) for the region to improve its overall relative position in labour productivity. It amounts to 26.52 per cent of what the East should achieve if it can just maintain the national average rate of (labour) productivity improvement in all sectors and in all provinces. Such rate of improvement is not very substantial and would, however, become much smaller after the deduction of structural change effect.

In the Middle, we find (on the threshold of 1985) that all provinces have negative sectoral structure effect, giving rise to a total of RMB -46.0996 per labour for the whole region. The overall relative gross competitiveness effect is negative: RMB -13.4664 per labour. As a result, in 1989, the realized average labour productivity in the Middle is RMB 59.566 lower than what it should attain if it could keep up with the national average growth rate of labour productivity. Deterioration of the Middle's relative position is mainly due to drastic decrease in competitiveness of three traditional industrial centres, Shanxi, Jilin and Hubei, with respective losses of RMB -131.1308, -142.5487 and -62.1303 per labour equivalent to 54.06 per cent, 50.39 per cent and 25.10 per cent of the hypothetical increase. All other provinces except Hunan experience some improvement of relative gross competitiveness. However, the improvement is not substantial. In fact, only Jiangxi can attain sufficient increase of relative competitiveness (RMB 72.2485 per labour equivalent to 47.93 per cent of the hypothetical increase) to offset the negative sectoral structure effect so that it can improve its relative position in 1989. Disappointingly, the relative gross competitiveness of Hunan, the least productive province, declines in 1989. Thus, the most important task for the Middle is to rescue the three traditional industrial centres, Shanxi, Jilin and Hubei, and halt the deterioration of their relative productivity competitiveness.

In the West, on the whole, the sectoral structure effect is negative (RMB -42.6249 per labour). Although the relative gross competitiveness effect is positive (RMB 22.2457 per labour), it is still not large enough for the region to uphold its relative position in 1989. Nevertheless, the improvement in relative gross competitiveness in the West is quite astonishing. It implies that (on a cross-sectional basis) the relationship between the growth rate and the level of labour productivity in China follows a U-shaped line, different from the two famous competing theories in development literature — the inverted U-shaped hypothesis and the polarization hypothesis. For China, both the relatively less-developed "new comers" and the relatively developed provinces grow above the national average at the expense of the mid-level developing areas.

Analysis at the provincial level shows that all provinces in the West have unfavourable sectoral structure effect (at the threshold of 1985). In the Southwest, Sichuan and Guizhou, the most populous and the least productive provinces, experience a diminution of relative gross competitiveness which reinforces the negative sectoral structure effect and leads to the decline of their relative position in 1989. Guizhou's deterioration is especially severe. Although Yunnan does enjoy a quite substantial improvement in relative productivity competitiveness (RMB 93.3797 per labour, equivalent to 86.44 per cent of the hypothetical increase), its negative sectoral structure effect is quite large, however, while its labour force is small relative to those of Sichuan and Guizhou combined. The Southwest (among other geographical regions) is one of the most stagnant regions during 1985-1989. The Northwest, however, shows a very different picture. All of the five provinces experience a certain degree of improvement in relative gross competitiveness. The positive competitiveness effect is large enough for Gansu, Ningxia and particularly Xinjiang to improve their relative (productivity) position in 1989. Nevertheless, as the employment size of the Northwest is still small relative to the Southwest, their combined gain is still insufficient to offset the loss of relative competitiveness in the Southwest plus the negative sectoral structure effect. Generally speaking, in 1985 the average labour productivity in the Northwest is already higher than that of the Southwest provinces. Thus, inter-provincial productivity disparity within the West widens further in 1989.

In short, on the threshold of 1985, all the three regions have negative sectoral structure effect which happens to be positive only in a few highly industrialized municipalities (DUCG) and provinces. Thus, in addition to measures for improving productive efficiency, appropriate inter-sectoral reallocation of labour (together with complementary inputs) should be pursued. In general, the employment structure of the East is less unfavourable compared with the Middle and the West. Concerning relative gross productivity competitiveness, it is found that on average both the most and the least productive regions experience some improvement but the Middle suffers a loss. On a provincial basis, the relative competitiveness of the most productive traditional economic centres and the least productive province, Guizhou, suffer deterioration. On the contrary, the most famous outward-oriented provinces which are late comers to industrialization show improvement.

The relative gross productivity competitiveness computed above includes effects other than changes in productive efficiency. In order to have a more accurate estimate of real changes in productive efficiency, we attempt to isolate the impact of the intra-regional-inter-sectoral labour reallocation effect on overall average labour productivity. However, the method adopted in this chapter does not take into account the impact of changes in the use of other factors of production such as capital and inter-sectoral differences in capital productivity, owing to the lack of provincial and sectoral data on capital stock. The impact thus isolated should be the gross effect only.[11] The resultant measure of relative productivity competitiveness is better than the original gross productivity competitiveness for assessing changes of competitiveness in the productive efficiency of labour input. Yet, it cannot completely isolate the impact of labour reallocation as long as capital is essential and variable, and still includes the impact of factors other than productive efficiency changes. Nevertheless, for comparison purpose we may call it relative net (labour) productivity competitiveness in contrast with the above relative gross (labour) productivity competitiveness.

Table 13 shows the relative net (labour) productivity competitiveness. On a regional basis, if there were no change in employment structure in all provinces and municipalities (DUCG), the average labour productivity of the East in 1989 would be lowered by RMB 40.121 per labour, over 47 per cent of the original relative gross competitiveness effect. The relative net competitiveness effect is then RMB 44.2424 per labour, equivalent to 13.905 per cent of the hypothetical increase (should average gross competitiveness be maintained in all sectors for each and every province). Thus, in the East intra-regional inter-sectoral structure changes in employment account for about 12.614 per cent of the hypothetical (gross productivity) increase. In the Middle, holding sectoral employment structure in all provinces constant would cut the relative gross productivity competitiveness of the region by RMB 13.4052 per labour. The resultant relative net productivity competitiveness effect is RMB -26.8717 per labour, equivalent to -14.06 per cent of the hypothetical increase. Thus, the sectoral structure change has contributed 7.016 per cent of the hypothetical increase in the Middle. In the West, holding sectoral employment structure constant would reduce overall average labour productivity of the region by RMB 6.1384 per labour which is equivalent to 4.418 per cent of the hypothetical increase. The resultant relative net productivity competitiveness is RMB 16.1073 per labour, equivalent to 11.59 per cent of the hypothetical increase. In short, changes in sectoral employment structure in 1989 relative to 1985 do contribute to some increase in the average labour productivity in the three regions. The greatest contribution (both absolutely and relatively) occurs in the East followed by the Middle and the West.

Table 13 Relative net labour productivity competitiveness for provinces and regions, 1985-1989

	ΔY_{Pr}	RC_n	RNPrC
Beijing	611.0334	-80.8304	-0.1168
Tianjin	601.3081	-138.8170	-0.1876
Hebei	155.2047	-56.5425	-0.2670
Liaoning	527.7781	-35.7972	0.0728
Shanghai	1276.8302	-283.6558	-0.1818
Jiangsu	445.4894	127.3242	0.4002
Zhejiang	365.9212	119.8543	0.4871
Fujian	320.1124	121.8395	0.6145
Shandong	291.5919	94.9554	0.4829
Guangdong	294.3816-324.3829	60.2593-90.2606	0.2574-0.3855
Guangxi	62.5390	-32.8654	-0.3445
East[1]	362.3130	44.2424	0.1391
Shanxi	102.3093	-140.2560	-0.5782
Inner Mongolia	163.7650	-3.4880	-0.0209
Jilin	211.6955	-71.1946	-0.2517
Heilongjiang	381.8002	-3.5363	-0.0092
Anhui	119.4584	-22.2605	-0.1571
Jiangxi	235.8482	85.0966	0.5645
Henan	121.8275	-18.7359	-0.1333
Hubei	197.2206	-50.3327	-0.2033
Hunan	99.3311	-40.1501	-0.2879
Middle[1]	164.1988	-26.8717	-0.1406
Sichuan	90.1496	-44.5959	-0.3310
Guizhou	50.9258	-51.3260	-0.5020
Yunnan	216.3744	108.3430	1.0029
Shaanxi	228.1002	58.7685	0.3471
Gansu	305.6213	127.5728	0.7165

Table 13 (Continued)

Qinghai	189.4508	26.7330	0.1643
Ningxia	212.9794	32.4907	0.1800
Xinjiang	351.5963	153.9930	0.7793
West(1)	155.0636	16.1073	0.1159

Sources: As for Table 1A.

Notes: ΔY_{Pr} = change in overall average labour productivity due to improvement in productive efficiency only, keeping sectoral employment structure unchanged. For province k in region j,

$$\Delta Y_{Prt+n} = \sum_{i} l_{ikjt} \Delta Y_{ikjt+n} ;$$

for region j,

$$\Delta Y_{Prt+n} = \sum_{k} \sum_{i} l_{ikjt} \Delta Y_{ikjt+n} .$$

For definition of variables and more detailed discussion see Note 11.

RC_n = relative competitiveness effect net of employment structural change effect

$= RC - (\Delta Yn - \Delta Y_{Pr})$

RNPrC = relative net labour productivity competitiveness; for computation method, see the Appendix.

(1) See Table 12.

On a provincial basis, we discover that for 10 out of 28 provinces and municipalities (DUCG), Beijing, Tianjin, Liaoning, Jiangsu, Jilin, Hubei, Jiangxi, Yunnan, Qinghai and Shaanxi, changes in employment structure per se lead to some decreases of average labour productivity; the losses of Jilin and Beijing are substantial. Shanghai, Guangdong, Shandong and Hebei, however, gain substantially from changes in the employment structure which raise their respective average labour productivity by RMB 255, 167-197, 118.3 and 74.79. In general, those provinces which experience rapid growth of labour productivity (for instance those famous outward-oriented coastal provinces) do experience growth-conducive changes in employment structure. On the contrary, with the exception of Shanghai, the traditional economic centres cannot gain much, or even lose, from changes in the employment structure. On the whole, after deducting the structural change effects, the advantage of the East (particularly of the outward-oriented provinces) in labour productivity improvement over the interior regions is reduced. In fact, measured relatively in relation to a hypothetical growth, the relative net productivity competitiveness in the West turns out to be close to that in the East. As a matter of fact, in the West, the relative net competitiveness effect accounts for 10.02 per cent of its actual increase in average labour productivity, almost at par with that attained in the East (10.99 per cent).

Certainly, the relative net productivity competitiveness measures based on the five sectors may in fact reflect intra-sectoral labour reallocation effect rather than real changes in productive efficiency. Indeed, by decomposing the industrial sector into five sub-sectors: extraction industry, raw materials industry, heavy manufacturing (processing) industry, light industries using raw materials from agriculture, and light industries using raw materials from non-agricultural products, we discover that the output share in the East is biased towards light industrial production especially the one manufacturing from raw materials from non-agricultural products, while those of the Middle and the West are biased towards heavy industrial production. The Middle is biased towards extraction industries and raw material industries, particularly the former. The West is biased towards all the three sub-sectors of heavy industry. By applying the modified "Shift-Share Model" to identify the sources of industrial growth, we find that the gross industrial output in the East grows faster than the national average rate in 1989 over 1985 by RMB 21.17 billion which can be decomposed into the sectoral structure effect (RMB 8.136 billion) and the competitiveness effect (RMB 13.037 billion). The sectoral structure effect accounts for nearly 40 per cent of the above-average growth of output. As for the Middle, in 1989 (compared with 1985), the gross industrial output is RMB 10.7119 billion below the hypothetical level (attained with the national average industrial growth rate) of which 58.625 per cent is attributable to the negative sectoral structure effect. Concerning the West, the realized industrial output in 1989 is RMB 10.123 billion lower than the hypothetical level, of which the negative competitiveness effect accounts for 18.35 per cent. Since the growth rate of labour productivity in China always correlates with the output growth rate, so changes in relative labour productivity competitiveness in the industrial sector (especially in the Middle) should be partially attributable to shift in the employment structure within the industrial sector. Unfortunately, because of data inadequacy we cannot proceed with the analysis at a higher level of sectoral disaggregation.

IV. Concluding Remarks

Judging from the experience of 1985-1989, the three-tier gradated regional development strategy (if effectively implemented) resulted in larger inter-regional disparities in per capita national income and overall average labour productivity. The income and productivity gaps between the East (the relatively more productive region), the Middle and the West (at the threshold of 1985) widened. By applying the modified "Shift-Share Model" to identify various sources of productivity growth and by isolating the impact of employment structural change on overall productivity changes, we find that the gradated regional development strategy did result in a higher relative net labour productivity competitiveness in the East which, however, exceeded the West only moderately in 1989, much out of intuition.

For spatial maximization of static resource allocative efficiency, relatively more resources should be allotted to those relatively more productive regions as increasing returns prevail. Such practice should definitely enlarge inter-regional income and productivity disparities. On the other hand, if more resources are allocated to the relatively less productive "new comers," at least in the short run inter-regional income disparity will be narrowed but at the expense of resource allocative efficiency. The present dilemma faced by the Chinese authority is that, with the autonomy previously bestowed by the central government, in the name of the acceleration of reform and the pursuit of an open door policy, the local authorities do possess considerable capability to counteract state policies deemed unfavourable to them. The authorities of the under-privileged areas (according to the gradated regional development strategy) have tried by all means to violate the strategy in order to maintain their relative competitiveness. As a matter of fact, even if the gradated development strategy were followed by the under-privileged regions in the early stage — without a fair, nation-wide income redistribution mechanism effectively controlled by the state, to relieve the financial problems of the under-privileged regions — continual widening productivity and income disparities would push the under-privileged regions to press the state for special treatment comparable to the privileged regions. Under intense political pressure, the state would make concession. Once one of the regions succeeded, others would follow immediately. How can the gradated regional development strategy be effectively implemented if such "keeping up with the Joneses' effect" prevails? Furthermore, in the face of huge intra-regional-inter-sectoral disparities in productivity, given the existing price and profit structures which are biased in favour of the more productive industrial sector especially light industries, how can we expect that the local authorities would contract the output of the relatively productive product, (in which they have a comparative disadvantage) and increase the output level of less productive products (in which they have a comparative advantage)? Thus, most likely the so-called rational kernel of the gradated regional development strategy — the law of comparative advantage — will not work without government intervention or drastic and comprehensive changes in the existing inter-sectoral profit structure.

In fact, before nation-wide undistorted markets can be established and function efficiently for an effective pursuit of the gradated regional development strategy, it is essential for the central government to control and operate a nation-wide income redistribution mechanism effectively so as to contain the unfavourable impact of cumulative causation effect on under-privileged areas, otherwise the "Joneses' effect," competing for preferential treatment will spread so much that the gradated development strategy cannot last long. Besides, measures should be adopted to strengthen the linkage and multiplier effects generated by the growth poles so as to enhance the spread or trickle-down effect on the less developed regions for shortening the painful period of growing regional disparities, which certainly demands substantial improvement in transportation and communication facilities as well as in material supplies conditions. Finally, as long as huge inter-sectoral disparities in productivity exist, regional discriminatory (inter-sectoral neutral) policies per se cannot function effectively to rectify sectoral disproportion problems. Regional-cum-sectoral discriminatory policies (on a comparative advantage basis) are theoretically the best policies which, nevertheless, presuppose a great capability on the part of the state to control and reallocate resources effectively and rationally.

Notes

1. See for instance, Nijkamp (1984), especially pp. 270-277.
2. For a detailed discussion of the impact of Maoist thought and the war preparation campaign in response to the Vietnam war, see for instance, Hsueh and Woo (1986).
3. For instance, the percentage shares of gross industrial output contributed by the East, the Middle and the West in 1952 were 68.3 per cent, 27.4 per cent and 4.3 per cent respectively, changing to 59.2 per cent, 32.6 per cent and 8.1 per cent respectively in 1978. During the same period of time, the share of original value of industrial fixed assets changed from 72 per cent in the East and 28 per cent in the Middle and the West combined to 43.9 per cent and 56.1 per cent respectively. See Hsueh and Woo (1991), Table 17A, pp. 58-59. For a discussion

on changes in income disparities, please refer to the first part of Section II.

4. For example, during 1963-1982, the output-investment ratio within the Third-Front regions was RMB 0.256 lower than the coastal areas by a factor of 2.8. See Liu (1984), p. 27.
5. "Geographical Distribution and Policy for Regional Economic Development," an excerpt of the Seventh Five-Year Plan of The People's Republic of China for Economic and Social Development reprinted in *Beijing Review*, Vol. 29, No. 17, 28 April 1986, "Documents," pp. XI-XII.
6. The weighted coefficient of variation of per capita value (X_i) for the jth region:

$$\frac{1}{\overline{X}_i} \sum_j \sum_k (X_{ikj} - \overline{X}_i)^2 \, l_{ikj} ,$$

where $\overline{X}_i$ is the mean value of all X_i's for all j's;

X_{ikj} is the value of X_i for unit k in region j;

l_{ikj} is the proportion of the population or employment level related to X_i of unit k in region j against the overall population or employment level = $L_{ikj} / \sum_j \sum_k L_{ikj}$

where L_{ikj} is the total size of population or employment related to X_i of unit k in region j

$$\overline{X}_i = \sum_j \sum_k X_{ikj} \cdot l_{ikj} .$$

7. The weighted inter-provincial variance can be decomposed into intra-regional and inter-regional variances in the following way:

$$V_T = \sum_k (X_{ik} - \overline{X}_i)^2 \, l_{ik}$$

$$= \sum_j \sum_k [(X_{ik} - \overline{X}_{ij}) + (\overline{X}_{ij} - \overline{X}_i)]^2 \, l_{ikj}$$

$$= \sum_j \sum_k (X_{ik} - \overline{X}_{ij})^2 l_{ikj} + \sum_j (\overline{X}_{ij} - \overline{X}_i)^2 l_{ij}$$
$$+ \sum_j \sum_k (X_{ik} - \overline{X}_{ij})(\overline{X}_{ij} - \overline{X}_i) l_{ikj}$$

where k is province, j is region; k=1, 2.....28; j=1, 2, 3. V_T is total inter-provincial variance; l_{ij} is the proportion of the population or employment level in region j related to X_i against the overall population or employment level

$$= \frac{\sum_k L_{ikj}}{\sum_j \sum_k L_{ikj}} \; ; \; l_{ik} = \frac{L_{ik}}{\sum_j \sum_k L_{ikj}} .$$

For a definition of other variables, see Note 6.

The first term to the right of V_T is the intra-regional variance; the second term is the inter-regional variance, and the third is the cross term which is equal to zero if the first and second terms are not correlated.

8. If unweighed coefficient of variation is used as the measure of disparities, some different results arise. For instance, inter-provincial disparity in average labour productivity for all five sectors combined of the whole nation in 1989 did increase from 0.734 in 1985 to 0.748 although disparity in the East fell. Note that in general, the unweighed mean value and coefficient of variation in labour productivity are larger than the weighted counterparts except the mean value for industrial labour productivity in the Middle and for the whole nation. Such discrepancies are attributable to the allotment of a disproportionally large share of labour to the relatively less productive areas or (and) sectors. Similarly, given the unweighed mean and coefficient of variation, the weighted mean will rise and the weighted coefficient of variation will decline if the share of labour allotted to areas of below-average productivity is reduced. However, expanding the employment share of most productive areas will boost both the weighted mean and variation of coefficient. Nevertheless, the authors believe the weighted coefficient of variation is a better indicator to reveal variation of average labour productivity because it takes into account differences in labour share. Thus, analysis of labour productivity disparities in this chapter is primarily based on the weighted coefficient of variation.

9. The result is calculated as follows:

$$^{r}W_h = \frac{\sum_i Y_{iw} (l_{in} - l_{iw})}{\sum_i Y_{iw} l_{iw}} \times 100\%$$

where $^{r}W_h$ is the hypothetical proportionate increase in overall average labour productivity in the West if the West could adopt the average employment structure of the whole nation; Y_{iw} is the realized average labour productivity of sector i in the West; i=1, 2....5; l_{iw} is the employment share of i (against total employment in the West); l_{in} is the employment share of i for the whole nation.

10. For application of the "Shift-Share Model" see for instance, Paraskevopoulos (1974).

11. The method adopted is to decompose the realized change in average labour productivity into pure productivity change effect, employment structural change effect and the cross term

$$\Delta Y_{jt+n} = \sum_k \sum_i l_{ikjt} \Delta Y_{ikjt+n} + \sum_k \sum_i Y_{ikjt} \Delta l_{ikjt+n}$$
$$+ \sum_k \sum_i \Delta Y_{ikjt+n} \Delta l_{ikjt+n}$$

where ΔY_{jt+n} is the change in overall average labour productivity in region j in year t+n against that in year t; ΔY_{ikjt+n} is the change in average labour productivity in sector i of province k in region j in year t+n; Δl_{ikjt+n} is the change in employment share in sector i of province k in region j in year t+n.

The first term to the right of the equality sign is the productivity change effect, the second term is the employment structural change effect, while the third is the cross effect. The total impact due to employment structural change is

$$= \Delta Y_{jt+n} - \sum_k \sum_i l_{ikjt} \, \Delta Y_{ikjt+n} \, .$$

For a critique of this method and a discussion of a possible way to improve on it by incorporating the capital element, see for instance, Syrquin (1986).

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Appendix

The mathematical representation of the modified "Shift-Share Model" is as follows:

A. For province k

(1) Constant Share effect:

$$CS_k = \sum_i r \cdot Y_{ikt} \cdot l_{ikt}$$

where CS_k is the constant share effect for province k, r is the proportionate growth of national average labour productivity between the two given periods computed by

$$\frac{Y_{t+n}}{Y_t} - 1$$

(where Y_t, Y_{t+n} is the national average labour productivity of all sectors in years t and t+n respectively); Y_{ikt} is average labour productivity of sector i for province k in year t; l_{ikt} is the employment share of i for province k in year t.

(2) Sectoral Structure effect:

$$SS_k = \sum_i r_i \cdot Y_{ikt} \, l_{ikt} - \sum_i r \cdot Y_{ikt} \cdot l_{ikt}$$

where SS_k is the sectoral structure effect for k; r_i is the proportionate growth of the national average labour productivity of sector i.

(3) Relative Competitiveness effect:

$$RC_k = Y_{kt+n} - Y_{kt} - \sum_i r_i \cdot Y_{ikt} \cdot l_{ikt}$$

where Y_{kt} is the average labour productivity for all sectors combined in province k in year t = $\sum_i Y_{ikt} \cdot l_{ikt}$;

Y_{kt+n} is realized average labour productivity for all sectors combined in province k in year t+n = $\sum_i Y_{ikt+n} \cdot l_{ikt+n}$.

B. For region j

(1) Constant Share effect:

$$CS_j = \sum_k rY_{kjt} \cdot l_{kjt} = \sum_k \sum_i \cdot Y_{ikjt} \cdot l_{ikjt}$$

where Y_{kjt} is the average labour productivity for all sectors combined of province k in region j in year t; l_{kjt} is the employment share of province k in region j in year t; Y_{ikjt} is the average labour productivity of sector i in province k of region j in year t; l_{ikjt} is the employment share of sector i in province k of region j (against the total employment level of region j) in year t.

(2) Sectoral Structure effect:

$$SS_j = \sum_i r_i \cdot Y_{ijt} \cdot l_{ijt} - \sum_k \sum_i r \cdot Y_{ikjt} \cdot l_{ikjt}$$

where r_i is the proportionate growth of national average labour productivity of sector i; Y_{ijt} is the average labour productivity of sector i in region j in year t; l_{ijt} is the employment share of i in j in year t.

(3) Relative Competitiveness effect:

$$RC_j = Y_{jt+n} - Y_{jt} - \sum_k \sum_i r_i \cdot Y_{ikjt} \cdot l_{ikjt}$$

where RC_j is the relative competitiveness effect il region j. Y_{jt+n}, Y_{jt} is the average labour productivity for all sectors combined in region j in years t+n and t respectively.
The relative gross labour productivity competitiveness in j

$$= \frac{RC_j}{\sum_k \sum_i r_i \cdot Y_{ikjt} \cdot l_{ikjt}}.$$

The relative net labour productivity competitiveness in j

$$= \frac{RC_{jn}}{\sum_k \sum_i r_i \cdot Y_{ikjt} \cdot l_{ikjt}}$$

where RC_{jn} is RC_j net of the impact of employment structure change on overall average labour productivity

$$RC_{jn} = RC_j - (Y_{jt+n} - Y_{jt} - \sum_k \sum_i l_{ikjt} \Delta Y_{ikjt+n})$$

$$= \sum_k \sum_i l_{ikjt} \Delta Y_{ikjt+n} - \sum_k \sum_i r_i \cdot Y_{ikjt} \cdot l_{ikjt}$$

where ΔY_{ikjt+n} is the change of average labour productivity in sector i of province k in region j in year t+n against that in year t.

4

The Impact of Reform on China's State Industry
A Regional Perspective

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I. Introduction

China's partial and somewhat hesitant approach to the transition from central planning toward a more market-oriented system provokes widely differing reactions. Disagreement is particularly sharp with regard to the impact of reform policy on industry, the sector universally recognized as the most difficult to reshape. Some observers (e.g., Stepanek 1991; Prybyla 1990; Putterman 1992) insist that little has changed, especially in large-scale firms within the state sector. Prybyla, for example, believes that "China's experience with partial economic changes and halfway reforms since 1979, culminating in the Tiananmen massacre and systemic recidivism, is an object lesson in the futility of taking the capitalist road without going all the way to advanced democratic capitalism" (1990:187); he reports that "the great majority" of Chinese economists whom he encountered during 1987-1988 shared his view on the "futility" of gradualism (1990:194).

This critical view is challenged by a number of studies (e.g., Chen, Jefferson and Singh 1992; Jefferson, Rawski and Zheng 1992a, 1992b; Rawski 1994) that cite gains in productivity and efficiency as well as quantitative evidence of accelerated innovation and effective profit-linked incentives to support the view that reform initiatives, although partial and incomplete, have brought substantial and beneficial improvements in the performance of Chinese industry. This perspective coincides with the picture emerging from a variety of World Bank reports (e.g., World Bank 1990) that portrays China's economy as one in which market forces are gradually gaining momentum, leading to the expectation that they may well overpower the remnants of central control over prices and allocation within a relatively short period.

One objective of this chapter is to discover what light an investigation of regional behaviour patterns can shed on this contentious matter. Our focus on state-owned industry penetrates to the heart of recent debates. If information on cross-provincial behaviour patterns in state industry reflects substantial impact of market-like forces, it will be difficult for critics of China's reform to insist that little has changed. Results showing no substantive impact of market forces will raise difficult questions for those who argue that reform has altered behaviour patterns throughout the economy.

There are many other reasons for exploring the regional dimensions of China's reform experiment. China is a huge nation with an enormous industrial sector. China's industrial work force is larger than the total industrial employment of all other third-world nations combined. Industrial employment, capital stock, and output in most of China's provinces exceed the comparable averages for third-world nations.

Like many large nations, China has a long history of spatial inequality. The People's Republic, established in 1949, inherited an economy in which industrial activity was overwhelmingly concentrated around Shanghai and in the three northeastern provinces of Liaoning, Jilin, and Heilongjiang. It is widely believed that subsequent efforts to redistribute industrial capacity, motivated by security considerations, regional ambitions, and a desire to eradicate what was seen as a legacy of semi-colonial development, burdened the economy with vast amounts of under-utilized and even useless industrial capital in interior regions (Naughton 1991). This perception draws support from numerous cost and productivity comparisons showing that industrial producers in Shanghai and other coastal regions typically achieved lower unit costs and higher productivity levels (e.g., bicycles or sewing machines produced per man-year or per square meter of factory space) than comparable plants in the interior, even without adjusting for the typically superior quality of products from coastal regions. What were the dimensions of inter-provincial productivity variation in Chinese industry prior to the start of economic reform? How does the order of magnitude of regional productivity differentials in Chinese industry compare with similar figures for other large nations?

Did reform expand inter-regional differentials in industrial productivity? The new policies of the reform decade have acted with particular force on coastal areas, particularly in the southeast, which have recorded unprecedented growth of industrial output, personal income, and manufactured exports. There is a widespread perception that the reforms have disproportionately benefited regions that already enjoyed relatively high living standards and development opportunities through a combination of historical legacy and official policy prior to the start of reform.

The topic of regional industrial development thus offers an opportunity to investigate a sequence of significant and controversial issues. Do we find large performance gaps between developed coastal provinces and lagging interior regions prior to reform? Is the reform period associated with a widening of inter-regional gaps in industrial productivity? Is there evidence of a substantial role for market forces under the semi-planned economic regime of the 1980s?

To approach these issues, we have used a recently published compilation of retrospective provincial statistics (State Statistical Bureau 1990), supplemented by provincial statistical publications, to construct a data set that covers state-owned independent accounting units in industry (mining, manufacturing, and utilities) for the years 1978-1990 in 26 of China's 30 provinces (Hebei and Shandong are excluded because of data gaps; Tibet is omitted because it has no significant industrial sector; the recently created province of Hainan is also excluded).[1] Independent accounting units (excluding, for example, repair works attached to China's railways) account for the bulk of industrial activity; the state sector is an important, but no longer dominant contributor to industrial production — its share of aggregate industrial output dropped from 80.7 per cent in 1978 (State Statistical Bureau 1985) to slightly below 50 per cent in recent years (see Jefferson, Rawski and Zheng 1992a). In compiling data from this source, we have tried to eliminate the most serious inconsistencies between Chinese statistical conventions and international statistical practice. These procedures are summarized in Appendix 1 at the end of this chapter.

The result of these manipulations is a data set that, while far from perfect, offers a picture of regional industrial activity that is internally consistent, reasonably congruent with standard accounting procedures, and covers a substantial time period. Previous efforts to examine regional development trends (e.g., Lardy 1978) have of necessity relied on a far weaker statistical base.

The remainder of the chapter is structured as follows: in Section II, we present models of regional production and describe the results of statistical estimation of two such models. Section III applies the statistical results to the questions posed in the introduction. Section IV summarizes our findings. Two appendices are attached to this chapter. Appendix 1 describes how the data are compiled. Appendix 2 provides a list of abbreviations for the provinces which are consistently used throughout this chapter.

II. Estimation Methods and Data

Functional Specifications

The production-function approach is adopted to estimate the absolute and relative efficiencies of the industrial sectors across provinces over time. A production function is first postulated for each province:

$$y_{it} = A_i(t, \underline{z}_{it}) f(\underline{x}_{it}). \tag{1}$$

The subscripts i and t denote the ith province and period t respectively; y_{it} is the gross value of industrial output (GVIO) of the ith province in year t; $\underline{x}_{it} = (x_{1it}, \ldots, x_{Pit})$ is a vector of P inputs. Following Jefferson et al. (1992a), the vector of input $\underline{x}_{it}$ consists of capital (K_{it}), labour (L_{it}) and intermediate inputs (M_{it}). All the variables are evaluated at constant 1980 prices.

$A_i(t, \underline{z}_{it})$ may be regarded as the absolute efficiency of the ith province. Loosely speaking, if $f(\underline{x}_{it})$ is regarded as a composite index of inputs, then $A_i(t, \underline{z}_{it})$ is the output per unit of composite input. The term t represents time and $\underline{z}_{it}$ is a vector of explanatory variables affecting efficiencies. The provinces may then be ranked according to their levels of efficiency. The method suggested by Schmidt and Sickle (1984) is adopted here. For each year, the relative efficiency index for the ith province is defined as

$$E_i = \frac{A_i}{A^*}, \quad A^* = \max_i (A_i) \tag{2}$$

where A_i is the absolute efficiency level of the ith province. E_i is equal to 1 if the ith province has the maximum efficiency. Otherwise, E_i is less than 1. Relatively to other provinces, the smaller the value of E_i is, the less efficient is a province.

To render equation (1) amenable to statistical estimation, the functional forms of $A_i(.)$ and $f(.)$ have to be specified and a random disturbance term v_{it} appended to the regression equation. Our modelling strategy is to first postulate a translog production function and then test whether log-linearity and constant returns to scale hold.[2] $A_i(.)$ and $f(.)$ assume the following forms:

$$\ln f(\underline{x}_{it}) = \sum_{k=1}^{P} \beta_{ki} \ln x_{kit} + \frac{1}{2} \sum_{h=1}^{P} \sum_{k=1}^{P} \beta_{hki} \ln x_{hit} \ln x_{kit} \quad (3)$$

$$A_i(t, \underline{z}_{it}) = \exp(\alpha_{0i} + \alpha_{1i} t + \underline{z}_{it}^T \underline{\delta}_i) \quad (4)$$

β_{ki}, β_{hki}, α_{0i}, α_{1i} are parameters; $\underline{\delta}$ is a vector of coefficients associated with the vector $\underline{z}_{it}$. Taking the natural logarithm of equation (1) results in the regression equation to be estimated. If $\beta_{hki} = 0$, h, k = 1, 2, 3, then the production function is log-linear. Furthermore, constant returns to scale imply that $\Sigma_k \beta_{ki} = 1$. Thus the translog specification allows us to test the two hypotheses above using F tests. If constant returns to scale are not rejected, then the functional form will be Cobb-Douglas.

The specification of the efficiency term in equation (4) requires an explanation. The parameter α_{0i} may be viewed as the time-invariant effect of some inherent quality of a province on efficiency. It is a conventional practice in the estimation of production functions to assume that the term A_i is a function of time and is identified loosely as technological change. Our specification of A_i assumes that the "rate of technological change" varies across provinces, i.e., α_{1i} varies across provinces. Besides the time-invariant and time-varying terms discussed above, other specific factors which may affect efficiencies in the Chinese context are also incorporated into A_i.[3] In this connection, the urban reforms since 1984 may also have had some impact on efficiency. To capture the effects of this regime switching, the provinces are classified into three groups — coastal, central and western provinces. Three dummy variables — RDC, RDI and RDW — are then introduced to capture the effects of urban reforms. In principle, one may assign dummy variables to the provinces. However, this will drastically reduce the degree of freedom. In any case, the above specification seems to fit our data nicely.

For each province, there are data for only 13 years (from 1978 to 1990). The small degree of freedom renders separate regression for each province inaccurate. If the cross-section and time-series data of the provinces are pooled together, then the degree of freedom may be increased considerably. In the final analysis, whether one should go ahead with pooling depends on the stability of the coefficients across provinces. Data limitations however compel us to assume that the coefficients corresponding to the factor inputs are stable across provinces. In terms of equation (3), $\beta_{ki} = \beta_{kj}$ for all i and j, and $\beta_{hki} = \beta_{hkj}$ for all i and j.

Fixed-effects (FE) and random-effects (RE) models are applied to our data set.[4] In the FE model, the intercept terms α_{0i} are assumed to be fixed and different. Essentially, the FE model is a linear regression model with dummy variables assigned to all the provinces. In FE model, z_{it} = (RDC, RDI, RDW).

The RE model assumes that α_{0i} is random. Thus, the model may be estimated using the generalized least square estimation method. We have experimented with two different RE models. The first one (RE1) includes exactly the same variables as those in the FE model stated above. The only difference is the assumption on α_{0i}. In the second model (RE2), three dummy variables for the three municipalities, i.e., Beijing (DBJ), Tianjin (DTJ) and Shanghai (DSH) are included so that z_{it} is equal to (RDC, RDI, RDW, DBJ, DTJ, DSH). In other words, the three municipalities are assumed to have *both* fixed and random effects on efficiencies to take into account the fact that the three cities are fundamentally different from the other provinces. It turns out that the estimated results of the first RE model are not as good as the second one. Thus, we only report the estimates of the second model. Finally, to recover the intercepts of individual provinces (i.e., α_{0i} in the RE model, the following formula proposed by Schmidt and Sickle (1984) is adopted:

$$\alpha_{0i}^{*} = \frac{1}{T} \sum_{i=1}^{T} (\alpha_0^{*} + \varepsilon_{it}^{*})$$

where α_{0i}^{*} is the estimated intercept term for the ith province; α_0^{*} is the estimated mean of the random variable α_{0i}; ε_{it}^{*} is the residual of the regression analysis for the RE model.

Data Issues

The provincial data for our empirical analysis are official statistics in provincial statistical yearbooks and publications of the State Statistical Bureau (SSB).[5] Only independent accounting enterprises in the state industrial sector for the period 1978-1990 are included in our study. The rest of this section will give a brief description of the data leaving the details to Appendix 1.

(A) Industrial Output

The provincial output is the GVIO at 1980 prices. Since the explanatory variables include material inputs, gross instead of net output value is used as the dependent variable in the regression analysis.

(B) Capital

Capital stock data are derived from the net value of fixed assets.[6] Two major problems are encountered. Chinese capital stock figures are just the sum of historical net investments at current prices. To arrive at the real capital stock, the net investment in fixed assets is first derived by subtracting last years net value of fixed assets from that of the current year. It is then deflated by a price index for capital stock. Ideally, each province should have its own price deflator. Instead, the national price deflator in Chen et al. (1988a, 1988b) is applied to the investment figures of all the provinces because of data limitations. The series in Chen et al. (1988a, 1988b) has been extended from 1985 to 1990.

The second problem is that fixed assets of independent accounting enterprises invariably include such service facilities as staff quarters, schools, clinics and retail stores. Following Chen et al. (1988a, 1988b), residential construction is deducted from fixed assets.[7]

(C) Labour

The employment data are mid-year figures. Many employees in state-run industrial enterprises are not directly involved in the production process e.g., medical workers in enterprise-run clinics, clerks in retail stores, etc. No separate figures are available for these types of workers. Following Chen et al. (1988b), the employment figures are multiplied by the share of non-residential to total capital stock to make crude allowance for the deficiency of the data.

(D) Material Inputs

As pointed out in Jefferson et al. (1992a), material inputs often constrain industrial productivity in China. The inclusion of this third input variable contributes to a more complete evaluation of China's industrial productivity. The value of material inputs is derived by subtracting net output value (NVIO) and depreciation (DEPR) from GVIO (see Appendix 1). Since data for the value of depreciation are not available, they are derived using gross and net fixed capital assets.[8] Comparing with the published data for depreciation available for some years, our estimates of depreciation seem to have understated the value of depreciation. Until better depreciation data are published, our estimates have to be used.

Empirical Findings

The regression results for the FE and RE models are reported in Table 1. We only report the results for the Cobb-Douglas cases because the translog and log-linear specifications are rejected in favour of the Cobb-Douglas production function.

On the whole, the regression results for the FE model are reasonable. The estimated coefficients of the logarithm of capital-labour (LNKLR) and material-labour (LNMLR) ratios have the expected signs and are statistically significant. With regard to RDC, RDI and RDW, i.e., the three dummy variables for regime switching, the reforms introduced since 1984 have positive and statistically significant effects on the three regions. The independent variables ranging from T1 to T26 are the time trends for the provinces; the abbreviation (in brackets) associated with each time trend variable in Table 1 is that of the province in question. Their coefficients correspond to α_{1i} in the above discussion. Most of these rates are statistically significant.

Table 1 Estimates from the random-effects and fixed-effects models

	Random effects		Fixed effects	
	Estimates	t-ratios	Estimates	t-ratios
LNKLR	.058115	2.46932	0.86846	2.17598
LNMLR	.710990	33.5171	.613254	21.9308
RDC	.044002	4.13605	.052067	4.87110
RDI	.024977	2.10832	.031148	2.60330
RDW	.034899	2.84867	.043172	3.47315
DBJ	.287585	6.03374		
DTJ	.202696	4.33400		
DSH	.373135	7.38610		
T1(BJ)	-.0009088	-.319133	.00160059	.534265
T2(TJ)	-.00267324	-.860829	.000600371	.175908
T3(SAX)	-.00507084	-1.82693	-.00246503	-.821631
T4(IM)	.00453132	1.57888	.010990	3.47893
T5(LN)	-.00158910	-.563331	-.00173380	-.571554
T6(JL)	.00934852	3.12721	.014871	4.43536
T7(HLJ)	-.00631394	-2.15222	-.00780132	-2.35305
T8(SH)	-.010961	-3.41766	-.00967124	-2.52687
T9(JS)	.00521461	1.66184	.00778880	2.16200
T10(ZJ)	.00815624	2.62251	.012010	3.43507
T11(AH)	.00354178	1.24042	.00734604	2.36085
T12(FJ)	.00938600	3.12437	.014889	4.38996
T13(JX)	.00808554	2.69030	.016846	4.96287
T14(HEN)	.00564095	1.95103	.00966317	3.00758
T15(HUB)	.010542	3.58566	.015862	5.14338
T16(HUN)	.00920917	3.21981	.014222	4.60246
T17(GD)	.013694	3.78294	.021028	5.03891
T18(GX)	.010601	3.43509	.017962	5.19147
T19(SC)	.00658226	2.31506	.013136	4.25315
T20(GZ)	.016887	5.61614	.025684	7.73135
T21(YN)	.023130	7.42741	.030725	8.93522
T22(SHX)	.00535678	1.85974	.011602	3.72182
T23(GS)	-.00172965	-.631634	-.0004176	-.146626
T24(QH)	.00543787	1.71636	.011032	3.18700
T25(NX)	-.00250566	-.839318	.00300103	.925417
T26(XJ)	.00557778	1.64419	.00997253	2.47847
Intercept	.346303	19.4433		

Table 1 (Continued)

Source: Regression results based on data described in Appendix 1.

The results for the RE model (RE2) are also meaningful and the estimates have the right signs. Three dummies for Beijing, Tianjin and Shanghai (DBJ, DTJ and DSH) are included to capture any fixed effects of the three cities on top of their random effects. The three municipalities are shown to have fixed and positive effects on efficiencies.

Which of the two models should be chosen? Both of them have nice statistical results. The Hausman specification test suggests that the error term of the FE model may not be orthogonal to the regressors. However, as pointed out above, the corresponding RE model, i.e., RE1 (not reported in this chapter), is less satisfactory than RE2 reported in Table 1. Since it is difficult to choose between these two models, two sets of figures on relative efficiencies are presented based on the two models.

III. Interpretation of Production Function Analysis

What can the production-function analysis described in the previous section contribute to our understanding of the important and often controversial issues raised in the introduction? Although the estimation results suggest that the specifications underlying our calculations fit rather well with the realities of Chinese industry, the inevitable weaknesses of data, arbitrariness of adjustments, and our own inability to distinguish clearly between alternative models incorporating "fixed effects" and "random effects" in the specification of efficiency change should warn us to confine our attention to patterns that emerge clearly from our results.

The first question concerns efficiency trends during the reform period. Here, our results reported in Tables 4A and 5A show a marked trend for the absolute level of industrial efficiency to increase over time. The estimated growth rates of provincial industrial productivity tend to be larger under the fixed-effects model than with the random effects specification. In either model, however, on average, a specific combination of fixed assets, labour, and materials generated more real output near the end of our period than at the beginning. If we compare the initial and terminal years, 1978 and 1990, we find that absolute efficiencies increased for all but two (fixed effects) or three (random effects) provinces. The finding of rising efficiency parallels the conclusions of other studies that have used aggregate and municipal data to investigate productivity trends in state industry (Chen et al. 1988b; Jefferson, Rawski and Zheng 1992a).

What of the contribution of rising efficiency to output growth? Under constant returns to scale, a specification that seems to fit the present data set, output growth can easily be decomposed into components associated with changes in the quantity of each factor of production, in this case, labour, fixed assets, and materials. For the Cobb-Douglas production function, the contribution of each factor is equal to the output elasticity of the factor multiplied by the growth rate of that factor. Instead of following the residual approach, the contribution of efficiency is set equal to the growth rate of the term $A_i(t, z_{it})$ which represents absolute efficiency. The results of such decomposition appear in Tables 2 and 3. Simple averages of the contributions over the entire period 1978-1990 are computed. Although the generally lower rates of efficiency growth under the random effects specification lead to lower contributions (including some negative elements) to output growth, the two calculations produce broadly similar results. In general, increased input of materials into the production process constitutes the chief impetus to higher output. The contribution of efficiency growth is typically small. Both the small contribution of efficiency change and the dominant role of increased materials consumption coincide with results obtained in other studies of state industry during the 1980s (Jefferson, Rawski and Zheng 1992a).

Though not reported in Tables 2 and 3, the year 1983/1984 constitutes a significant exception to this pattern. The urban reforms introduced during 1984 offered industrial units unprecedented opportunities to purchase a portion of their inputs and sell some of their outputs in markets with relatively uncontrolled prices. Because we anticipate that these changes may have substantially affected the behaviour of industrial enterprises, we introduce a dummy variable intended to capture the impact of any "regime change" associated with these policy initiatives. The "regime change" variables turn out to exercise an important influence in our estimation. Owing to our specification of regime change as a one-shot jump in efficiency in 1984, efficiency changes for that year were strikingly larger than in earlier or later years; their contribution to output growth matched or even surpassed the individual contribution of any factor of production. An appropriate interpretation of the jump is that the 1984 reforms elicited significant changes in enterprise behaviour patterns, although their effects need not have been confined to 1983/1984 (as is assumed in our estimation procedure).

Table 2 Sources of growth: fixed-effects model

	GK	GM	GL	GA
BJ	0.000597	0.045173	0.008747	0.00594
TJ	0.006565	0.045614	0.00452	0.004939
SAX	0.005864	0.049775	0.012443	0.000131
IM	0.006	0.055966	0.009352	0.013586
LN	0.005667	0.045851	0.00887	0.002605
JL	0.006719	0.059969	0.007627	0.017467
HLJ	0.007437	0.053373	0.008183	-0.00521
SH	0.007068	0.031521	0.00271	-0.00533
JS	0.009095	0.064263	0.00971	0.012128
ZJ	0.008699	0.068987	0.01134	0.016349
AH	0.007472	0.059667	0.010129	0.011685
FJ	0.007431	0.062956	0.008256	0.019228
JX	0.005932	0.068125	0.008342	0.019442
HEN	0.006881	0.056262	0.009428	0.012259
HUB	0.00684	0.072587	0.012171	0.018457
HUN	0.005583	0.054641	0.007998	0.016818
GD	0.008701	0.079432	0.007123	0.025367
GX	0.005925	0.06029	0.003933	0.022301
SC	0.004153	0.058367	0.00733	0.016734
GZ	0.004063	0.058248	0.004707	0.029282
YN	0.005056	0.056575	0.003395	0.034322
SHX	0.004925	0.059103	0.007704	0.0152
GS	0.003724	0.04556	0.007818	0.00318
QH	0.008377	0.066383	0.007836	0.01463
NX	0.00525	0.064798	0.008465	0.006599
XJ	0.009533	0.075042	0.009859	0.01357

Source: Authors' computation results.
Notes: GK = contribution to growth due to capital.
GL = contribution to growth due to labour.
GM = contribution to growth due to material inputs.
GA = contribution to growth due to higher efficiency.

Table 3 Sources of growth: random-effects model

	GK	GM	GL	GA
BJ	0.003988	0.052395	0.006735	0.002758
TJ	0.043839	0.052906	0.00348	0.000994
SAX	0.039158	0.057733	0.009581	-0.00299
IM	0.040066	0.064913	0.007201	0.006613
LN	0.037848	0.053181	0.00683	0.002078
JL	0.044871	0.069556	0.005873	0.01143
HLJ	0.049667	0.061906	0.006301	-0.00423
SH	0.047198	0.03656	0.002087	-0.00729
JS	0.060741	0.074536	0.007476	0.008881
ZJ	0.058091	0.080016	0.008731	0.011823
AH	0.0499	0.069206	0.007799	0.007209
FJ	0.049628	0.073021	0.006357	0.013053
JX	0.039614	0.079016	0.006424	0.010167
HEN	0.045951	0.065257	0.00726	0.007722
HUB	0.045676	0.084192	0.009371	0.012624
HUN	0.037282	0.063376	0.006159	0.011291
GD	0.058104	0.092131	0.005485	0.017361
GX	0.03957	0.069929	0.003028	0.014268
SC	0.027737	0.067698	0.005644	0.009491
GZ	0.027135	0.06756	0.003624	0.019795
YN	0.033765	0.065619	0.002614	0.026038
SHX	0.032892	0.068552	0.005932	0.008265
GS	0.02487	0.052844	0.00602	0.001179
QH	0.05594	0.076995	0.006034	0.008346
NX	0.03506	0.075157	0.006518	0.000403
XJ	0.063662	0.087039	0.007592	0.008486

Source: Authors' computation results.
Notes: GK = contribution to growth due to capital.
GL = contribution to growth due to labour.
GM = contribution to growth due to material inputs.
GA = contribution to growth due to higher efficiency.

Table 4A Absolute efficiencies: fixed-effects model

	BJ	TJ	SAX	IM	LN	JL	HLJ
1978	1.955	1.787	1.405	1.191	1.610	1.281	1.707
1979	1.958	1.789	1.402	1.204	1.607	1.300	1.694
1980	1.961	1.790	1.398	1.217	1.604	1.320	1.681
1981	1.965	1.791	1.395	1.230	1.602	1.339	1.668
1982	1.968	1.792	1.391	1.244	1.599	1.359	1.655
1983	1.971	1.793	1.388	1.258	1.596	1.380	1.642
1984	2.080	1.890	1.428	1.312	1.678	1.445	1.680
1985	2.083	1.891	1.425	1.326	1.675	1.466	1.667
1986	2.086	1.892	1.421	1.341	1.673	1.488	1.654
1987	2.090	1.893	1.418	1.356	1.670	1.511	1.642
1988	2.093	1.894	1.414	1.371	1.667	1.533	1.629
1989	2.096	1.896	1.411	1.386	1.664	1.556	1.616
1990	2.100	1.897	1.407	1.401	1.661	1.580	1.604

	SH	JS	ZJ	AH	FJ	JX	HEN
1978	2.184	1.550	1.483	1.386	1.337	1.189	1.345
1979	2.163	1.563	1.501	1.396	1.357	1.209	1.358
1980	2.142	1.575	1.519	1.407	1.377	1.230	1.372
1981	2.121	1.587	1.537	1.417	1.398	1.251	1.385
1982	2.101	1.600	1.556	1.428	1.419	1.272	1.398
1983	2.081	1.612	1.574	1.438	1.440	1.293	1.412
1984	2.171	1.712	1.679	1.526	1.540	1.357	1.471
1985	2.150	1.725	1.699	1.537	1.563	1.380	1.485
1986	2.129	1.738	1.719	1.549	1.587	1.404	1.499
1987	2.109	1.752	1.740	1.560	1.610	1.427	1.514
1988	2.088	1.766	1.761	1.572	1.635	1.452	1.529
1989	2.068	1.779	1.782	1.583	1.659	1.476	1.544
1990	2.048	1.793	1.804	1.595	1.684	1.501	1.558

Table 4A (Continued)

	HUB	HUN	GD	GX	SC	GZ	YN
1978	1.396	1.342	1.417	1.268	1.274	1.171	1.232
1979	1.419	1.362	1.447	1.291	1.291	1.202	1.271
1980	1.441	1.381	1.478	1.315	1.308	1.233	1.311
1981	1.464	1.401	1.509	1.339	1.326	1.265	1.351
1982	1.488	1.421	1.541	1.363	1.343	1.298	1.394
1983	1.512	1.441	1.574	1.388	1.361	1.332	1.437
1984	1.584	1.508	1.694	1.488	1.440	1.427	1.547
1985	1.610	1.530	1.730	1.515	1.459	1.464	1.596
1986	1.635	1.552	1.766	1.543	1.478	1.502	1.645
1987	1.662	1.574	1.804	1.571	1.498	1.541	1.697
1988	1.688	1.597	1.842	1.599	1.517	1.581	1.750
1989	1.715	1.619	1.881	1.628	1.538	1.622	1.804
1990	1.743	1.643	1.921	1.658	1.558	1.665	1.861

	SHX	GS	QH	NX	XJ
1978	1.263	1.532	1.238	1.334	1.384
1979	1.277	1.531	1.252	1.338	1.398
1980	1.292	1.530	1.266	1.342	1.412
1981	1.307	1.530	1.280	1.346	1.426
1982	1.323	1.529	1.294	1.350	1.440
1983	1.338	1.528	1.308	1.354	1.455
1984	1.413	1.595	1.381	1.418	1.534
1985	1.430	1.595	1.396	1.422	1.549
1986	1.447	1.594	1.412	1.427	1.565
1987	1.463	1.593	1.427	1.431	1.581
1988	1.481	1.593	1.443	1.435	1.597
1989	1.498	1.592	1.459	1.439	1.613
1990	1.515	1.591	1.475	1.444	1.629

Source: Authors' calculation based on regression results.

Table 4B Relative efficiencies: fixed-effects model

	BJ	TJ	SAX	IM	LN	JL	HLJ
1978	0.895	0.819	0.644	0.545	0.737	0.587	0.782
1979	0.906	0.827	0.648	0.557	0.743	0.601	0.783
1980	0.916	0.836	0.653	0.568	0.749	0.616	0.785
1981	0.926	0.844	0.658	0.580	0.755	0.631	0.786
1982	0.937	0.853	0.662	0.592	0.761	0.647	0.788
1983	0.947	0.862	0.667	0.605	0.767	0.663	0.789
1984	0.958	0.871	0.658	0.604	0.773	0.666	0.774
1985	0.969	0.880	0.663	0.617	0.779	0.682	0.776
1986	0.980	0.889	0.668	0.630	0.786	0.699	0.777
1987	0.991	0.898	0.672	0.643	0.792	0.716	0.779
1988	1.000	0.905	0.676	0.655	0.796	0.733	0.778
1989	1.000	0.904	0.673	0.661	0.794	0.742	0.771
1990	1.000	0.903	0.670	0.667	0.791	0.752	0.764
	SH	JS	ZJ	AH	FJ	JX	HEN
1978	1.000	0.710	0.679	0.635	0.612	0.544	0.616
1979	1.000	0.723	0.694	0.646	0.627	0.559	0.628
1980	1.000	0.735	0.709	0.657	0.643	0.574	0.640
1981	1.000	0.748	0.725	0.668	0.659	0.590	0.653
1982	1.000	0.761	0.740	0.680	0.675	0.605	0.666
1983	1.000	0.775	0.757	0.691	0.692	0.622	0.679
1984	1.000	0.788	0.773	0.703	0.709	0.625	0.678
1985	1.000	0.802	0.790	0.715	0.727	0.642	0.691
1986	1.000	0.816	0.808	0.727	0.745	0.659	0.704
1987	1.000	0.831	0.825	0.740	0.764	0.677	0.718
1988	0.998	0.844	0.841	0.751	0.781	0.694	0.730
1989	0.987	0.849	0.850	0.755	0.791	0.704	0.736
1990	0.976	0.854	0.859	0.760	0.802	0.715	0.742

Table 4B (Continued)

	HUB	HUN	GD	GX	SC	GZ	YN
1978	0.639	0.615	0.649	0.581	0.584	0.536	0.564
1979	0.656	0.630	0.669	0.597	0.597	0.556	0.588
1980	0.673	0.645	0.690	0.614	0.611	0.576	0.612
1981	0.690	0.660	0.712	0.631	0.625	0.597	0.637
1982	0.708	0.676	0.734	0.649	0.639	0.618	0.663
1983	0.727	0.693	0.757	0.667	0.654	0.640	0.691
1984	0.730	0.695	0.780	0.686	0.663	0.657	0.713
1985	0.749	0.712	0.805	0.705	0.679	0.681	0.742
1986	0.768	0.729	0.830	0.725	0.694	0.706	0.773
1987	0.788	0.746	0.856	0.745	0.710	0.731	0.805
1988	0.807	0.763	0.880	0.764	0.725	0.756	0.836
1989	0.818	0.773	0.897	0.777	0.733	0.774	0.861
1990	0.830	0.782	0.915	0.789	0.742	0.793	0.886
	SHX	GS	QH	NX	XJ		
1978	0.578	0.701	0.567	0.611	0.634		
1979	0.591	0.708	0.579	0.619	0.646		
1980	0.603	0.715	0.591	0.627	0.659		
1981	0.616	0.721	0.603	0.635	0.672		
1982	0.630	0.728	0.616	0.643	0.686		
1983	0.643	0.735	0.629	0.651	0.699		
1984	0.651	0.735	0.636	0.653	0.707		
1985	0.665	0.742	0.649	0.662	0.721		
1986	0.679	0.749	0.663	0.670	0.735		
1987	0.694	0.756	0.677	0.679	0.750		
1988	0.707	0.761	0.690	0.686	0.763		
1989	0.715	0.759	0.696	0.687	0.769		
1990	0.722	0.758	0.703	0.688	0.776		

Source: Authors' computation based on regression results.

Table 5A Absolute efficiencies: random-effects model

	BJ	TJ	SAX	IM	LN	JL	HLJ
1978	1.883	1.727	1.424	1.395	1.450	1.409	1.471
1979	1.882	1.722	1.417	1.402	1.448	1.422	1.462
1980	1.880	1.718	1.410	1.408	1.445	1.436	1.453
1981	1.878	1.713	1.403	1.415	1.443	1.449	1.444
1982	1.876	1.709	1.396	1.421	1.441	1.463	1.435
1983	1.875	1.704	1.389	1.427	1.438	1.477	1.426
1984	1.957	1.776	1.417	1.470	1.501	1.528	1.453
1985	1.955	1.771	1.410	1.477	1.498	1.543	1.443
1986	1.954	1.766	1.402	1.484	1.496	1.557	1.434
1987	1.952	1.762	1.395	1.490	1.494	1.572	1.425
1988	1.950	1.757	1.388	1.497	1.491	1.586	1.416
1989	1.948	1.752	1.381	1.504	1.489	1.601	1.407
1990	1.947	1.748	1.374	1.511	1.487	1.616	1.399
	SH	JS	ZJ	AH	FJ	JX	HEN
1978	2.031	1.439	1.435	1.418	1.419	1.394	1.418
1979	2.009	1.447	1.447	1.423	1.432	1.405	1.426
1980	1.987	1.454	1.459	1.429	1.446	1.416	1.434
1981	1.965	1.462	1.471	1.434	1.459	1.428	1.442
1982	1.944	1.470	1.483	1.439	1.473	1.439	1.450
1983	1.923	1.477	1.495	1.444	1.487	1.451	1.458
1984	1.987	1.552	1.575	1.514	1.569	1.500	1.504
1985	1.966	1.560	1.588	1.519	1.583	1.512	1.512
1986	1.944	1.568	1.601	1.525	1.598	1.524	1.521
1987	1.923	1.576	1.614	1.530	1.613	1.537	1.529
1988	1.902	1.584	1.627	1.536	1.629	1.549	1.538
1989	1.881	1.593	1.641	1.541	1.644	1.562	1.547
1990	1.861	1.601	1.654	1.547	1.659	1.574	1.556

Table 5A (Continued)

	HUB	HUN	GD	GX	SC	GZ	YN
1978	1.429	1.419	1.436	1.411	1.411	1.409	1.422
1979	1.445	1.432	1.455	1.426	1.420	1.433	1.455
1980	1.460	1.446	1.476	1.441	1.429	1.457	1.490
1981	1.475	1.459	1.496	1.457	1.439	1.482	1.524
1982	1.491	1.473	1.517	1.472	1.448	1.507	1.560
1983	1.507	1.486	1.537	1.488	1.458	1.533	1.597
1984	1.561	1.538	1.629	1.572	1.520	1.614	1.692
1985	1.578	1.552	1.651	1.588	1.530	1.642	1.732
1986	1.595	1.566	1.674	1.605	1.540	1.670	1.772
1987	1.611	1.581	1.697	1.622	1.550	1.698	1.813
1988	1.629	1.596	1.720	1.640	1.560	1.727	1.856
1989	1.646	1.610	1.744	1.657	1.570	1.757	1.899
1990	1.663	1.625	1.768	1.675	1.581	1.787	1.944
	SHX	GS	QH	NX	XJ		
1978	1.406	1.448	1.408	1.419	1.433		
1979	1.413	1.446	1.415	1.415	1.441		
1980	1.421	1.443	1.423	1.412	1.449		
1981	1.429	1.441	1.431	1.408	1.457		
1982	1.436	1.438	1.439	1.405	1.465		
1983	1.444	1.436	1.446	1.401	1.473		
1984	1.503	1.484	1.506	1.447	1.534		
1985	1.511	1.482	1.514	1.444	1.543		
1986	1.519	1.479	1.522	1.440	1.551		
1987	1.528	1.476	1.531	1.437	1.560		
1988	1.536	1.474	1.539	1.433	1.569		
1989	1.544	1.471	1.547	1.429	1.578		
1990	1.552	1.469	1.556	1.426	1.586		

Source: Authors' calculation based on regression results.

Table 5B Relative efficiencies: random-effects model

	BJ	TJ	SAX	IM	LN	JL	HLJ
1978	0.927	0.850	0.701	0.687	0.714	0.694	0.725
1979	0.937	0.857	0.706	0.698	0.721	0.708	0.728
1980	0.946	0.865	0.710	0.709	0.727	0.723	0.731
1981	0.956	0.872	0.714	0.720	0.734	0.737	0.735
1982	0.965	0.879	0.718	0.731	0.741	0.753	0.738
1983	0.975	0.886	0.722	0.742	0.748	0.768	0.742
1984	0.985	0.894	0.713	0.740	0.755	0.769	0.731
1985	0.995	0.901	0.717	0.751	0.762	0.785	0.734
1986	1.000	0.904	0.718	0.759	0.766	0.797	0.734
1987	1.000	0.903	0.715	0.763	0.765	0.805	0.730
1988	1.000	0.901	0.712	0.768	0.765	0.813	0.726
1989	1.000	0.899	0.709	0.772	0.764	0.822	0.722
1990	1.000	0.898	0.706	0.776	0.764	0.830	0.718
	SH	JS	ZJ	AH	FJ	JX	HEN
1978	1.000	0.709	0.707	0.698	0.699	0.686	0.698
1979	1.000	0.720	0.720	0.709	0.713	0.699	0.710
1980	1.000	0.732	0.734	0.719	0.728	0.713	0.722
1981	1.000	0.744	0.749	0.729	0.743	0.727	0.734
1982	1.000	0.756	0.763	0.740	0.758	0.741	0.746
1983	1.000	0.768	0.778	0.751	0.773	0.755	0.759
1984	1.000	0.781	0.793	0.762	0.789	0.755	0.757
1985	1.000	0.794	0.808	0.773	0.806	0.769	0.769
1986	0.995	0.803	0.820	0.781	0.818	0.780	0.778
1987	0.985	0.808	0.827	0.784	0.827	0.787	0.784
1988	0.975	0.812	0.835	0.787	0.835	0.794	0.789
1989	0.966	0.817	0.842	0.791	0.844	0.802	0.794
1990	0.956	0.822	0.850	0.795	0.853	0.809	0.799

Table 5B (Continued)

	HUB	HUN	GD	GX	SC	GZ	YN
1978	0.704	0.699	0.707	0.695	0.695	0.694	0.700
1979	0.719	0.713	0.725	0.710	0.707	0.713	0.725
1980	0.735	0.728	0.743	0.726	0.719	0.733	0.750
1981	0.751	0.742	0.761	0.741	0.732	0.754	0.776
1982	0.767	0.758	0.780	0.757	0.745	0.775	0.803
1983	0.784	0.773	0.800	0.774	0.758	0.797	0.830
1984	0.786	0.774	0.820	0.791	0.765	0.812	0.851
1985	0.803	0.790	0.840	0.808	0.778	0.835	0.881
1986	0.816	0.802	0.857	0.822	0.788	0.855	0.907
1987	0.826	0.810	0.869	0.831	0.794	0.870	0.929
1988	0.835	0.818	0.882	0.841	0.800	0.886	0.952
1989	0.845	0.827	0.895	0.851	0.806	0.902	0.975
1990	0.854	0.835	0.908	0.860	0.812	0.918	0.999
	SHX	GS	QH	NX	XJ		
1978	0.692	0.713	0.693	0.699	0.706		
1979	0.704	0.720	0.705	0.705	0.717		
1980	0.715	0.726	0.716	0.711	0.729		
1981	0.727	0.733	0.728	0.717	0.741		
1982	0.739	0.740	0.740	0.723	0.754		
1983	0.751	0.747	0.752	0.729	0.766		
1984	0.756	0.747	0.758	0.728	0.772		
1985	0.769	0.754	0.770	0.735	0.785		
1986	0.778	0.757	0.779	0.737	0.794		
1987	0.783	0.756	0.784	0.736	0.799		
1988	0.788	0.756	0.789	0.735	0.804		
1989	0.793	0.755	0.794	0.734	0.810		
1990	0.797	0.755	0.799	0.732	0.815		

Source: Authors' computation based on regression results.

How large is the performance gap, measured in terms of "relative efficiency," between provincial industry in different regions of China? Here, we encounter the first of several surprising results. Data compiled in Tables 4B and 5B display the ratio, for each province and year, of the absolute coefficient of industrial efficiency for that province to the corresponding absolute efficiency of the province (invariably Shanghai or Beijing) achieving the highest level of absolute efficiency in that particular year. Relative efficiency thus falls between zero and unity, with the latter figure assigned in each year to the province with peak absolute efficiency.

These data show that the "relative efficiency gap" between the provinces recording the highest and lowest levels of absolute efficiency is rather small. The minimum levels are shown below:[9]

	1978	1984	1990
Fixed effects	0.536(GZ)	0.604(IM)	0.667(IM)
Random effects	0.686(JX)	0.713(SAX)	0.706(SAX)

These data are indeed surprising when compared with results of a study of regional manufacturing productivity in the United States, in which an analysis based on the fixed effects and random effects specifications showed relative efficiency coefficients at the state level as low as 0.37 or 0.50 depending on which of two estimation methods was employed (Beeson and Husted 1989). However, the results for the United States and for China come from different models; Beeson and Husted assume that the differences in productivity across provinces are fixed over time whereas we allow the differences to change over time. A more precise comparison may lead to a different outcome.

These results are unexpected because, in comparison with Shanghai and Beijing, the economies of China's less developed interior regions appear "laggard" or "backward" in terms of human capital endowments, manufacturing experience, access to information, etc. to a degree that one might expect to surpass

comparable differences between more and less developed regions of the United States by a very large magnitude.

The extent of market forces in China's post-reform economy is hotly debated; nobody would suggest that China's 1978 economy represented a marked system. Yet, the unexpected results shown above are not the only hint that forces in China's pre-reform economy might somehow have generated market-like outcomes in certain areas. The findings reported here are consistent with the hypothesis that increasing competitive pressures from the non-state sector increase the x-efficiency of the firms.

The unexpectedly small gap between the absolute efficiency of industrial activity in the most and least productive provinces is partly attributable to administered prices that discriminate against certain industries, notably coal and (in recent years) petroleum. These industries, along with most individual producers, invariably lose money simply because administered prices necessitate the sale of substantial (though declining) portions of production at prices that fall below (incompletely measured) production costs at even the most productive facilities. It is no surprise that two of the three provinces reporting lower absolute efficiency in 1990 than in 1978 are major centres of extractive energy industries: Shanxi, China's coal capital, and Heilongjiang, a major producer of both crude oil and coal (Shanghai, the third province in this category, has no extractive industry).

On the other hand, it is possible that non-market aspects of China's planned economy artificially reduce inter-provincial differences in absolute efficiency. This could easily arise from our use of "gross output value" rather than "sales" as a measure of output, particularly under circumstances in which inferior or even useless outputs are turned out because producers can count such "goods" toward the objective of plan fulfilment. Indeed, we can find many sources that document instances of Chinese state enterprises producing inferior or useless outputs both before and during the reform period.

Although such behaviour might contribute to a deceptive compression of absolute levels of provincial industrial efficiency at one time (for example, 1978), its dynamic consequences are quite different. During the 1980s, the proportion of industrial output transacted under market-like conditions (e.g., at flexible or "negotiated" prices) has risen steadily. One recent report states that the value of industrial output under mandatory planning has been reduced to merely 16 per cent (Gui 1992). In another report, the ex-factory prices of "means of production for industrial use," which were entirely state-determined in 1978, were distributed as follows: prices controlled by the state, 44.4 per cent; state-guided prices, 18.8 per cent; market-regulated prices, 36.8 per cent (Li 1992:17). Under these circumstances, particularly given the universal concern for financial performance now characteristic of Chinese state industry, the initial presence of unusually large quantities of inferior or useless output in the mix of products generated by certain provinces would lead to a substantial relative decline in measured absolute efficiency of those provinces (we omit reference to the technicalities concerning fixed and current prices, which might impede but would not eliminate this tendency).

If the special features of China's traditional planning system artificially compressed inter-provincial differences in "absolute efficiency" at the start of the reform period, we should expect the reform process to induce a progressively increasing dispersion of absolute and relative efficiencies. In fact, our data reveal the opposite tendency. The second surprising outcome of our study is the emergence of evidence showing a trend toward convergence in provincial efficiency levels during the reform period.

The extent of this convergence is evident from Table 6, which displays the coefficients of variation for estimated provincial efficiency parameters on an annual basis during 1978-1990. Under both the fixed effects and the random effects specifications, the coefficient of variation declines steadily between 1978 and 1983. Data from the fixed-effects model decline monotonically throughout the period of analysis. Under the random effects specification, the coefficient of variation fluctuates during 1983-1987 and then increases. In both cases, the 1990 figure is less than the initial one,

the margin of decline being much greater (decline of 35.3 per cent) in the case of fixed effects than for the random effects approach (decline of 12.3 per cent).

Table 6 Coefficients of variation of relative efficiencies

	Random-effects model	Fixed-effects model
1978	0.1037	0.1679
1979	0.0989	0.1598
1980	0.0946	0.1520
1981	0.0908	0.1445
1982	0.0875	0.1374
1983	0.0849	0.1308
1984	0.0872	0.1297
1985	0.0859	0.1242
1986	0.0854	0.1195
1987	0.0857	0.1154
1988	0.0868	0.1122
1989	0.0885	0.1099
1990	0.0910	0.1086

Source: Authors' computation based on the index of relative efficiencies in Tables 4 and 5.

Another view of the convergence process emerges from Table 7, which combines the data into regional groupings — eastern (coastal), central, and western provinces — based on standard Chinese geographic terminology (Agriculture 1991:408). The upper panel of Table 7 compares the simple average of provincial relative efficiency results in each of the three regions for 1978, 1984 and 1990. Results of the fixed-effects (FE) and random-effects (RE) models are tabulated separately. Two points emerge: differences between the regional averages are unexpectedly small (e.g., the 1978 figure for the coast is only 24 per cent above the corresponding figure for the western provinces using the FE data and 14 per cent with the RE data). Second, the inter-regional differences shrank perceptibly during the reform period: by 1990, the difference between east and west has shrunk to only 15 per cent with the FE data and six per cent with the RE data.

Table 7 Regional patterns of relative efficiency, 1978, 1984, 1990

	Fixed-effects model			Random-effects model		
	Coast	Central	West	Coast	Central	West
A. Simple average of provincial relative efficiencies						
1978	0.742	0.623	0.597	0.801	0.699	0.699
1984	0.815	0.681	0.677	0.857	0.763	0.774
1990	0.877	0.742	0.758	0.877	0.808	0.828
B. Coefficient of variation (unweighed) for provincial relative efficiencies						
1978	0.175	0.106	0.081	0.144	0.014	0.010
1984	0.123	0.072	0.050	0.111	0.037	0.048
1990	0.084	0.066	0.077	0.085	0.071	0.099

Source: Authors' calculation based on regression results.
Note: Province with maximum efficiency = 1.00 in each year.

The lower panel of Table 7 explores this apparent convergence process through separate calculation of coefficients of variation within each region. The results show that the shrinking of productivity differences between regions may have been accompanied by a process of productivity convergence within the three regions. Under the FE specification, the intra-regional coefficients of variation are uniformly lower in 1990 than in 1978; with one exception, the FE-based coefficients of variation show a monotonic downward trend in each of the three regions between 1978, 1984 and 1990. If we focus on the coastal region alone, both the FE and RE data point strongly to convergence of provincial efficiency coefficients. The RE specification produces 1978 absolute efficiency coefficients that are nearly identical within and across the provinces of the central and western regions (see Tables 4A and 5A). The figures for later years are somewhat dispersed, leading to an increase in the coefficient of variation for these regions during 1978-1984 and again between 1984 and 1990. Note that such divergence could arise from the unmasking of low-quality or useless production (as described above), perhaps associated with facilities built in interior provinces under the "Third-Front" security-oriented investment programme of the 1960s and 1970s.

The results summarized in Tables 6 and 7 have important implications for the regional character of economic reform in China. Some observers have expressed concern that the reform process may be widening inequalities between the relatively developed coastal regions and relatively under-developed interior areas. Certainly the most visible trappings of reform — export zones, experimental share markets, etc. — are concentrated along the coast, which also seems to enjoy the fastest growth rates for industrial output and personal incomes. In terms of industrial efficiency, however, our data show little sign of a bias favouring relatively advanced regions. Some of the convergence results suggest the opposite, that the 1980s may have witnessed a narrowing of inter-provincial variations in relative industrial efficiency (as measured by our models), with convergence particularly evident under the "fixed effects" specification and within the coastal region.

If the partial and incomplete diminution of inter-regional and intra-regional variations in the relative efficiency coefficients emerging from the analysis of provincial industrial data is accepted as a genuine phenomenon, what economic processes could explain this development? The observed pattern of declining variation in inter-provincial efficiency coefficients is unlikely to represent a series of coincidences. It is consistent with the hypothesis that, despite the incomplete nature of reform, market forces are beginning to "take hold" in China's industrial economy with the result that we begin to observe quantitative outcomes associated with the expected consequences of a shift from planning toward market-based allocation of resources and profit-centred investment decisions.

If market forces push toward the reduction or elimination of spatial inequalities in technical efficiency, we expect no comparable pressures under a system of socialist planning such as existed in China prior to reform. The injection of market forces into an economy formerly dominated by the state sector and monopolistic industrial organizations, competitive pressures induced by the rapid growth of non-state sectors may create pressures toward the equalization of technical efficiency. The regional efficiency measures that emerge from our estimation provide one way of determining whether Chinese reform has begun to generate such pressures. The case of the United States shows that this convergence process need not be complete even in an advanced market system (Beeson and Husted 1989).

We hypothesize that the convergence process suggested by our estimation results reflects the growing penetration of market forces in an economy that continues to embody a substantial, but declining range of restrictions, rigidities, and immobilities. The rapid growth of collective and private industries in the reform era created potent competitive forces which the state enterprises could not ignore if they were to remain viable and maintain the living standards of their employees. Despite very real and significant limitations on market processes and competition, the tendency toward convergence of relative efficiencies is a sign of market forces and competition gradually gaining ground.

First, the past decade has witnessed enormous expansion of markets for industrial materials (widely interpreted to include any sort of inter-industry purchase) and products. Instances of local protectionism, illustrated by "wool wars" and other conflicts over market shares and control of underpriced materials (e.g., Watson et al. 1989) cannot obscure the dominant trend toward broader markets for the outputs and material inputs of China's state industries.

There is a less visible but nevertheless substantial development of capital markets. Provincial and local governments, as well as individual enterprises (especially large ones like Capital Iron and Steel Company) routinely enter into a variety of transactions that have the effect of shifting fixed assets and loanable funds across administrative boundaries and between regional jurisdictions. These include various forms of horizontally integrated conglomerations, compensation trade (e.g., Shanghai provides funds to develop mineral production in Inner Mongolia, and receives supplies from the new or enlarged facilities), sub-contracting (which often includes provision of equipment, blueprints, etc.), and even outright takeover of facilities in distant locations through merger, purchase, or administrative combination. The rapid and near-complete compression of profit differentials among state, urban collective and rural industry that occurred during the 1980s (Rawski, forthcoming) could hardly have emerged without considerable transfers of funds and/or equipment across administrative demarcations and probably across geographic boundaries as well.

Labour mobility also increased during the 1980s, particularly among rural workers, who now move quite freely both within rural areas and between the countryside and the cities. Even the urban labour scene experienced modest increases in mobility, especially for highly skilled personnel. Turnover rates within the state sector (including commerce, public services, etc. as well as industry) in the late 1980s, although low, fall within the range of recent experience in Japan's large corporate sector (Jefferson and Rawski 1992). For highly skilled workers, the gradual relaxation of control over part-time and consulting arrangements has further enlarged opportunities for transfer of human capital.

This expansion of markets draws support from a massive increase in access to many varieties of information throughout China's economy. Particularly relevant in the current context are new opportunities to transfer new technology, blueprints, product designs, and marketing information across China's national and provincial boundaries. Although international transfers received by coastal provinces command great public attention, it is possible that transfers to interior regions, originating mostly from domestic sources, have made a greater impact on the economy.

These changes are matched by a greater sensitivity and responsiveness to market forces throughout the economy. One important component of the Chinese reform is a process of decentralization that has transferred substantial elements of economic decision-making from the centre to enterprises and to provincial and local governments. Although the distribution of new powers among these beneficiaries is disputed, as is the appropriateness of the uses to which they have put their new-found independence, it is clear that the reform has enhanced both the ability and the willingness of provincial governments to pursue their own development objectives and perceived comparative advantage.

In the Chinese case, we seek to determine the extent, if any, to which reforms have opened the door for market forces to compete with, and perhaps begin to outweigh state interventions in determining patterns and trends of economic performance. Our hypothesis is that the reforms have indeed created a sufficient mass of market-like institutions, decision processes, and allocative mechanisms to generate outcomes reflective of market forces even in state industry, formerly the core of China's system of mandatory planning and bureaucratic resource allocation. We anticipate that the relative importance of market forces is the greatest in the coastal regions that have experienced the most extensive reform efforts.

Although we cannot demonstrate conclusively that the growing strength of market forces is directly responsible for the (partial and incomplete) convergence of provincial productivity measures obtained in this study, these results are surely not consistent with the view that reform has hardly affected the behaviour of state enterprises, that "little headway seems to have been made in firming up... the 'soft budget constraint'" and that the impact of reform has not been sufficient to change long-standing patterns in which "managerial energies were not applied in efficiency-enhancing ways" (Putterman 1992:473, 478). The same findings fit

well with the notion that managers, workers, and enterprises in Chinese state industries, as well as their suppliers and customers, increasingly behave like participants in a market system (albeit one subject to extensive regulation and official intervention) rather than subordinates within an administrative hierarchy of central planning. Even the inconsistent results on productivity convergence (Table 7, lower panel) coincide with our hypothesis in the sense that convergence is greatest and most consistent among the coastal provinces that have surely experienced the greatest degree of reform impact.

IV. Conclusion

This chapter draws on a newly constructed panel data set covering independent accounting units within China's state industry at the provincial level to investigate issues of regional development and reform impact during the period 1978-1990. We estimate two separate sets of production models using "fixed effects" and "random effects" specifications for efficiency change, along with specific dummy variables for China's three province-level cities and for the "regime change" associated with the 1984 reforms. Our data, which include capital, labour, intermediate inputs, and gross output, adjusted to remove non-industrial inputs and to express output, fixed assets, and intermediate inputs in real terms, fit well with the Cobb-Douglas functional form under constant returns to scale.

The principal estimation results include the following:

1. There was a general increase in efficiency during the period 1978-1990.
2. Efficiency change contributed only modestly to the expansion of output, except for the year 1983/1984.

Both these results conform to the findings of earlier studies. Our estimates also lead to new and somewhat unexpected results:

3. Calculations of relative provincial efficiency indicate that:

- The gap between more and less developed regions is surprisingly small.
- This gap declined during the 1980s, suggesting that reform has not created differential advantages for the relatively developed coastal regions.
- There is evidence of a pattern of convergence among measures of provincial efficiency levels both nationally and across, as well as within, three broad regions: the coast, the centre, and the west. This suggests that the reform has led to a significant increase in market integration both nationally and within the coastal region.

These results seem consistent with the hypothesis that reform initiatives have successfully injected market forces into China's economy to the point where even state industry, formerly the core of state planning, now displays patterns of allocation and development that can be predicted from the analysis of market models.

The same results seem inconsistent with the view that partial and incomplete reforms such as those implemented by China's government during the past 15 years have not and cannot succeed, and that large and sustained improvements in productivity, efficiency, and absorption of new technology must await sweeping changes that completely demolish the inherited system of state enterprises.

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Notes

1. A complete list of the provincial publications used to compile our data set is available on request.
2. Hicks neutral technical change is assumed.
3. Our specification of A_i is similar to that of Prasnikar, Svejnar and Klinedirst (1992).
4. For a detailed discussion of the statistical properties of the fixed-effects and random-effects models, see Hsiao (1986).
5. The sources of the provincial data are available from the authors on request.
6. Quota working capital is excluded. The rationale may be found in Chen et al. (1988).
7. The details of the estimation method may be found in Appendix 1.
8. For details, see Appendix 1.
9. See Appendix 2 which contains a list of abbreviations for the provinces.

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Appendix 1

This section describes how the variables for the regression analysis are constructed.

A. Real Gross Value of Industrial Output

GVIO is in 1980 prices. For a limited number of provinces where published data on real output are not available, a price deflator for the state industrial sector is used. The price deflator for the *entire* state industrial sector is derived in the following way. Figures for GVIO at comparable prices are available. Nominal GVIO is then divided by GVIO in 1980 prices to arrive at the price deflator. It is to be noted that the output of the state independent accounting industrial enterprises makes up a predominant share of the output of the entire state industrial sector. One would thus expect that the price deflator for the entire state industrial sector is not a bad approximation.

B. Real Stock of Fixed Capital Excluding Residential Construction

Using the time series data for net value of fixed assets (KFN), the nominal non-residential investment in year t is then equal to:

$$DKFN_t = KFN_t - KFN_{t-1} - RES_t,$$

where KFN_t is the net value of fixed assets in year t and RES_t is residential investment in year t. The real stock of non-residential fixed capital is then equal to:

$$K_t = KFN_{1978} \times SH + \sum_{S=1979}^{t} \frac{DKFN_S}{PK_S}$$

where PK_s is the capital deflator for year s and SH is the estimated share of non-residential capital. It is to be noted that the initial capital stock is assumed to be equal to the nominal net value of fixed asset, i.e., KFN_{1978} adjusted for residential construction.

Data for KFN are not broken down into residential and non-residential investments. To estimate the share of non-residential investment, one reasonable proxy is the share of non-residential investment in the state industrial sector. Unfortunately, for many provinces no such data are found in published sources. Data for the entire state sector is thus used instead.

Total investment of the state sector consists of three categories: basic construction, renovation, and miscellaneous investments. Each type of investment includes residential construction. For most of the provinces, data on residential investment are only available for the first two categories of investment. Our estimates thus correspond to the share of non-residential investment in basic construction and renovation investment. In any case, the share of miscellaneous investment is relatively small. Residential investment for each type of investment is deducted from the respective value of investment to arrive at non-residential investment.

With regard to renovation investment, published data on non-residential investment often do not exist for the years 1978 and 1979. For these two years, the figures for the share of non-residential to total investment are those of basic construction investment. Since the amount of renovation investment was very small at the beginning of the reform era, the margins of error are likely to be very small. There are also a few provinces whose values of residential construction in renovation investment are missing for some years after 1980. To fill the gaps, it is assumed that residential investment grows at a constant rate between two points in time when data are available.

In computing the shares of non-residential investment, newly commissioned investment is the variable in the denominator.

To estimate the value of non-residential investment of the state independent accounting industrial enterprises, the shares for the entire state sector ($SHARE_t$) are applied to the change in the net value of fixed assets, i.e.:

$$DKFN_t = (KFN_t - KFN_{t-1}) * SHARE_t.$$

To deflate DKFN, the national capital deflator in Chen et al. (1988a) is used for all the provinces because of data limitations. The series is extended beyond 1985 using the same methodology as in Chen et al. (1988a). The series is normalized so that the value for 1980 is 100.

C. Mid-year Employment

For many provinces, published data for mid-year employment are not available. However, it is possible to recover the mid-year employment figures from labour productivity. The latter is defined as GVIO in 1980 prices divided by mid-year employment. Dividing labour productivity by real GVIO will result in an estimate of mid-year employment.

D. Material Inputs

The real value of material inputs is estimated as follows:

$$M_t = (GVIO_t/PQ_t) - (NVIO_t/PQ_t) - (DEPR_t/PK_t).$$

GVIO is the nominal gross value of output, PQ is the price deflator for GVIO, NVIO is net value of output and DEPR is the value of depreciation. Net value of output is always reported in nominal terms. The price deflator for GVIO is applied to the net value of output to arrive at real NVIO. The following formula is used to derive DEPR:

$$DEPR_t = (KFO_t - KFO_{t-1}) - (KFN_t - KFN_{t-1})$$

where KFO is the original value of fixed assets.

Appendix 2

The following is a list of the abbreviations for the provinces used throughout the chapter.

BJ	Beijing
TJ	Tianjin
SAX	Shanxi
IM	Inner Mongolia
LN	Liaoning
JL	Jilin
HLJ	Heilongjiang
SH	Shanghai
JS	Jiangsu
ZJ	Zhejiang
AH	Anhui
FJ	Fujian
JX	Jiangxi
HEN	Henan
HUB	Hubei
HUN	Hunan
GD	Guangdong
GX	Guangxi
SC	Sichuan
GZ	Guizhou
YN	Yunnan
SHX	Shaanxi
GS	Gansu
QH	Qinghai
NX	Ningxia
XJ	Xinjiang

5

The Impact of Reform on Chinese Industrial Productivity

Frances Perkins
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Cao Yong

Since being designated as a special economic zone, Xiamen has seen its output rise rapidly, but so has the volume of inputs used. This study attempts to determine the extent to which the growth of output has outstripped that of inputs. Eight major industrial sectors and three major types of firm organization — state, collective and joint venture — are examined. Collectively owned enterprises are wholly owned by groups of individuals or local governments. Joint ventures are jointly owned by local state enterprises and foreign firms. This study analyses whether the establishment of the special economic zone with its more lenient foreign exchange retention regime, a somewhat more flexible labour relations regime and enhanced infrastructural facilities, has had any significant impact on the total factor productivity performance of Xiamen industry.

I. Productivity Studies on China

Total factor productivity (TFP) growth is defined as the growth over time in output per unit of weighted inputs (such as labour, capital, energy and materials), where the weights are equal to the output elasticities of the respective inputs. The growth of total factor productivity is an indication of the growth in national living standards which can be achieved by improvements in the allocation and productivity of existing human, capital and material production factors. This can be compared to growth which is derived from the employment of increasing amounts of these factors. In the more successful developing and industrial countries, total factor productivity growth can account for about half of total output growth.

Total factor productivity increases can be achieved either by technological change, improved allocation of resources or scale economies, or by combinations of all three of these. Studies have been made assessing the level of total factor productivity growth by sector, location and type of ownership of industry, using national and regional industrial statistics (Jefferson 1989) and cross sectional data for particular industries like the iron and steel industry (Jefferson 1990) and for township, village and collective industries (Svejnar 1987).

The purpose of such studies has been to determine in which industries and regions, and under which policy regimes, total factor productivity growth has been the greatest, and to provide a guide to policy makers regarding which policy reforms are likely to be most effective in raising total factor productivity.

In recent years, there have been numerous studies by both foreign and Chinese scholars of productivity growth in Chinese industry (Chen et al. 1988a; Jefferson 1990). Despite quite impressive levels of output growth and the substantial capital deepening since 1949, a comparison of China with other developing and industrial countries demonstrates that there has been a disappointing level of total factor productivity growth since the late 1950s.

Total factor productivity growth has contributed very little to economic growth in China; only about 8 per cent of total economic growth, or 0.3 percentage points of GNP growth per annum between 1952 and 1981 (Table 1). This compares to an average total factor productivity growth contribution of 42 per cent for the Republic of Korea and 39 per cent for 19 developing countries.

Table 1 International comparison of total factor productivity growth

	GNP growth (% p. a.)		TFP growth as share of total growth (%)	
China[1]	A	B	A	B
1952-81	0.5	-1.0		-17
1952-75	0.3	-1.1	5	-18
1975-81	1.0	-0.3	17	-5
China's industry[2]	C	D	C	D
1953-85	2.3	1.9	23	19
1953-57	5.3	5.1	32	31
1957-78	0.8	0.4	9	5
1978-85	5.2	4.8	60	56
China's industry (current study)	C		C	
1980-85	12.7		5.8	
1986-89	10.7		-16.2	
Brazil[3]				
1950-60	3.7		54	
1955-70	2.1		34	
1960-74	1.6		22	
Republic of Korea				
1955-60[4]	2.0		47	
1955-70[5]	5.0		57	
1969-73[5]	4.1		42	
Spain[6]				
1956-65	5.0		44	

Table 1 (Continued)

Japan		
1952-71[7]	3.8	38
1952-64[8]	5.1	53
1953-71[9]	5.9	58
1955-71	2.9	25
1955-70[10]	5.6	55
1960-73	4.5	41
United States[5]		
1947-60	1.4	38
1960-73	1.3	30
Soviet Union[11]		
1950-60	1.9	32
1960-70	1.5	29
1970-75	0.1	3
Average for 19 developing countries[12]	2.0	31
Average for 12 industrial countries[12]	2.7	49

Notes: (1) World Bank (1985a), p. 39. A assumes a 60 per cent share for labour, 40 per cent for capital. B assumes a 40 per cent share for labour, 60 per cent for capital.
(2) Chen, et al. (1988a). C: capital stocks valued at 1980 prices. D: capital stocks valued at 1952 prices.
(3) Elias (1978).
(4) Chen (1977).
(5) Christensen et al. (1980).
(6) Balassa and Bertrand (1970).
(7) Jorgenson and Esaki (1973).
(8) Watanabe (1972).
(9) Denison and Chung (1976).
(10) Nishimizu and Hulten (1978).
(11) Bergson and Levine (1983), chapter 2.
(12) Chenery et al. (1986), chapter 2.

Other Chinese empirical studies support the finding that total factor productivity growth has made a negligible or even negative contribution to national income growth since the 1950s (Rawski 1980; Field 1983; Chow 1985; World Bank 1983; Tidrick 1986; Chen and Sang 1986; Pan 1986). A few studies estimate very modest increases in total factor productivity since reform was commenced (Chen et al. 1988a; Jefferson 1990; Shi et al. 1986; World Bank 1990). Nevertheless, it appears likely that a major potential source of real output and income growth in other developing and industrial countries has been forgone by China, at least prior to the reform period.

II. Trade and Foreign Investment Reforms in China, 1979-1991

China's open door policy on foreign investment and trade, initiated in the late 1970s, commenced a movement away from the position of self-sufficiency it had adopted with the Communist revolution in 1949. The open door policy was expected to provide China with a range of benefits, including access to modern technology to improve the efficiency of its antiquated industry and infrastructure, the creation of employment for its rapidly growing population, the expansion of export industries to provide foreign exchange and the introduction of Western management techniques, aimed at improving efficiency.

Between 1979 and 1980, four special economic zones were established in Shenzhen, Shantou, Zhuhai and Xiamen, in the southeastern provinces of Guangdong and Fujian. In April 1984, the opening of 14 large coastal cities (including Shanghai) to foreign investment was announced, and in 1987, five special economic zones were established in Hainan province.

The "*Coastal Area Economic Development Strategy*" was initiated in 1988, in a speech by Zhao Ziyang. He urged that China's coastal areas, with approximately 200 million people, should seize the opportunity of adjusting to international conditions by concentrating on producing labour-intensive goods for export. Foreign investment should be attracted by allowing the establishment of wholly foreign-owned, joint-venture and co-operative enterprises. Where necessary, raw materials and intermediate goods should be imported and the finished product exported after value was added in China. Zhao Ziyang also indicated that the reform of foreign trade enterprises would be accelerated, so that trading enterprises could take responsibility for their profits and losses.

The Pearl and Yangzi River deltas and parts of Fujian were allowed to adopt policies on foreign investment, taxation and profit remittance which were similar to those that existed in the zones and coastal cities. In 1990, it was announced that the Pudong special economic and industrial zone would be established in Shanghai, offering an even more liberal policy regime than in existing zones.

In order to attract foreign direct investment and to promote the transfer of advanced technology and the production of "high-tech" products, special inducements were offered in the zones to foreign investors. These inducements included the right to obtain duty draw-backs on imported inputs and capital goods, to "retain" 100 per cent of foreign exchange earnings, to expatriate profits, and to convert earnings needed to pay local costs at a secondary market rate which more closely reflected China's shadow exchange rate (Zhang 1987; Martin 1990; Lin 1991).[1] Labour hiring and firing were supposed to more closely reflect practices in market economies, though it is doubtful whether this in fact occurred. Foreign firms were also allowed access to local capital markets. In recent years, the latter have frequently offered lending rates which have been negative in real terms (Lin 1991).

In Xiamen, as in the other special economic zones, a new industrial estate, Huli, was established. In this estate, the municipal government provided subsidized factory space, specialized infrastructure such as back-up power supplies and international telecommunication facilities, accommodation for workers and villas for foreigners. As well, it attempted to stream-line zone firms' dealings with the Chinese bureaucracy. Improvements were also made to port, airport, road and rail infrastructure serving Xiamen. However, these facilities were provided at a high cost to the Chinese economy (Lin 1991). Administrative regulations remain confused and arbitrary, so it is still a matter for debate whether the zones yet provide a significantly more attractive investment environment for foreign firms other than overseas Chinese investors, despite the high cost of establishing them (Wall 1990; Wong 1987).

Firms in technology development zones in the open coastal cities are also given 100 per cent retention rights over their foreign exchange earnings. Firms in Fujian and Guangdong may retain only 30 per cent. Firms in the rest of the country, including Beijing and Shanghai, can retain only 25 per cent, but of this amount only half can be retained by the exporting firm — the other half goes to the local government (Zhang 1987:52). In practice, firms do not actually retain foreign exchange, only the right to buy it at the secondary market rate. At the end of 1990, the secondary market rate was US$1 = RMB¥5.75, compared to the official exchange rate of US$1 = RMB¥5.18. However, prior to the 1989 devaluation, this divergence was considerably larger, at RMB¥5.8, compared to an official rate of RMB¥3.7 to US$1.00. Rights of access to the secondary foreign exchange market could also be sold, effectively increasing exporters' returns from exporting.

There appears to be a similar gradation of policies regarding access to domestic borrowing, taxation of profits and access to foreign exchange for imported inputs, as occurs with foreign exchange retention. The zones in the open coastal cities (and some special regions like Tibet) receive the most favourable treatment; Guandong and Fujian provinces somewhat less preference; and the rest of the country the least. On a sectoral level, in the light industry, clothing and arts and craft industries, experimental reforms were introduced in 1988 with the abolition of export subsidies and their replacement with provisions allowing exporters the right to "retain" 75 per cent of their foreign exchange earnings. In January 1991, export subsidies were removed for the whole foreign trade sector, and the proportion of foreign exchange earnings retained by exporters increased. At the same time, the gains and losses made by foreign trade corporations were made their own responsibility.

One of the concerns of this study is to determine the prospects for improving the performance of China's manufactured export sector. Exports of manufactures have risen rapidly since the opening of China's economy in the late 1970s, but many domestic policy obstacles inhibit continued growth (Lin and Yang 1987). A range of policies has been developed to encourage export growth. It was hoped that the special economic zones and coastal cities would attract foreign capital and provide employment opportunities, hence expanding the factors drawn into the industrial export sector. It was anticipated that the firms located in these favoured areas would employ more advanced technologies and management practices, as well as benefit from more flexible labour and capital market policies, and more liberal trade and foreign exchange regulations. Firms in these zones and the coastal cities were therefore expected to achieve a rapid growth in the productivity of the factors they employed, and hence a more rapid rate of export growth.

III. Other Industrial and Economic Reforms

Enterprise management, pricing, labour and capital market reforms commenced in China in the 1980s but by the early 1990s were only partially completed. Enterprise reforms commenced in 1979 with the introduction of regulations designed to reduce centralized control over the activities of a limited number of selected firms, in order to judge the effect of these measures on efficiency. However, these reforms spread spontaneously to enterprises representing 60 per cent of output and 70 per cent of profits in the first year after 1979 (Johnson 1990). As a result, firms were allowed to retain part of their depreciation charges and profits, for reinvestment and the payment of bonuses to provide incentives to workers. A reduced proportion of investment was provided directly as

grants from controlling government departments, and a greater proportion from bank loans, which the firms were required to repay. It was also expected that capital charges would be levied to repay the state for the capital investments that they had made previously.

Of these initiatives, only the reforms relating to the retention of profits were fully implemented. This resulted in a substantial decline in revenue flowing to the central budget at a time when there was a major growth in investment associated with Hua Guofeng's ambitious 10 year development programme. There was also a spurt in local government investment in industry. This was a consequence of the increased incentives provided to local governments to invest in local industries, as a result of their right to retain some profits. Combined with pressures from workers for increased salaries and bonuses from retained earnings, these partially implemented and rather poorly thought-through reforms resulted in significant inflationary pressures, and major balance of payments and central government budget deficits. The latter reached 5.2 per cent of GDP in 1979 (Blejjer and Szapary 1989).

In 1981, profit contracting was introduced into smaller industrial enterprises to parallel the contract responsibility system which was by then working successfully in agriculture. Firms negotiated a base level of profits which were to be handed over to the state and were then allowed to retain between 20 and 100 per cent of the remainder. By 1982, this system had spread to 80 per cent of state enterprises. But it was an arbitrary and time consuming system. The level of profits to be achieved and surrendered could not be determined on the basis of any uniform formula because of the failure of input and output pricing to reflect true economic scarcities, the vast differences in the state's investment in different firms, and other state influences on the original choice of technology and location, all of which affected the current profitability of firms. Instead, the level of profits to be surrendered was agreed after protracted negotiations between firms and their line departments and local authorities. Since non-economic factors frequently influenced the outcome of these negotiations, their impact in improving resource allocation was not necessarily positive in all cases. This will be tested in the latter part of this study.

Labour market reform has also been attempted, but with limited success until recently. The system of permanent tenure for state enterprise workers remains substantially intact, despite attempts to introduce contract employment for new workers. Although 15 per cent of state enterprise workers are now on contracts, the lack of a social security system for unemployed workers still makes enterprises very reluctant to sack workers or fail to renew their contracts. Temporary workers from the countryside, employed for short-term and seasonal jobs are an exception to this system and can be used by enterprises to provide some flexibility if their activities have a seasonal nature. Recently announced reforms (August 1992) explicitly urge firms to trim their workforces to the minimum required. Redundant workers receive a proportion of their previous salary, with no bonuses, and are encouraged to seek work elsewhere. Increased flexibility will also be introduced into the promotion system (*China Daily*, 1/9/92).

The other area of labour reform attempted in the early 1980s was the introduction of bonuses aimed at improving the relationship between the productivity and remuneration of workers. There was a very narrow spread of wages between skilled and unskilled workers in China, and there was no differentiation on the basis of productivity of workers in the same skill categories. Bonuses provided an initial spurt to productivity. However, within a few years, the mentality of "all eating from one big pot" had reasserted itself, and bonuses were routinely paid at the same level to all workers, regardless of their productivity (Johnson 1990; White 1988; Cao 1992). This merely added to inflationary pressures and negated the earlier stimulus for improved labour productivity.

Reforms were also proposed for the banking system and the method of financing enterprise investment. Prior to 1978, all net revenue of enterprises was paid to the state, and all enterprise investment was allocated as grants directly to enterprises by the state agencies responsible. In 1984, a transition was commenced to

a more market-oriented system, whereby investment was financed by a mixture of re-invested enterprise profits, bank lending and state allocations. By 1988, 68.4 per cent of all enterprise investment and working capital requirements were met by bank loans (23.4 per cent in 1978). In both years, the bulk of the residual was met by government allocations (Zhang 1987).

As firms were supposed to repay loans with interest, the system was intended to ensure firms only invested in profitable activities. Banks also were supposed to be responsible for their losses and hence were expected to apply prudential standards and lend only for viable projects. A large number of factors have prevented these reforms having their intended effect, and there is apparently still no absolute requirement to repay loans. Firms cannot be bankrupted. Banks are not independent, but are subjected to pressure from local and provincial authorities to lend to preferred projects. Since banks' losses are always covered by their responsible agencies, there is no real incentive for them to resist pressure from local authorities.

At least initially, many provincial banks lacked the expertise to analyse the financial or economic viability of proposed projects. The apparently widespread practice of undertaking new investment projects without proper financial or economic analyses is likely to seriously impair future prospects for productivity growth and international competitiveness (World Bank 1985a). As nominal interest rates have been negative for many years since 1980, firms have had a great incentive to invest. These incentives for enterprises and local authorities have been enhanced by the decentralization of profit retention and taxation rights.

Serious price distortions create another major problem for reforming the system of allocating investment funds. Even if banks allocate funds to projects which are financially viable, at distorted prices, there is no guarantee that they will be economically beneficial to China. In a situation of continuing price distortions, a more market-oriented method of investment allocation through the banking system may actually result in a less rational and economically efficient allocation of resources than allocations under the Plan. Output of many industries, like raw and semi-processed materials, infrastructure services and energy are still subject to very low Plan prices. A financial assessment of investment proposals in these areas, using distorted prices, may show them to be unviable, but an economic assessment, based on shadow prices, which reflect true economic value, could indicate a high economic return to investments in these areas.

Price reform is the other major area in which reform has been attempted, but to date progress in this area has been slow. In 1981, a dual price system was introduced, under which firms sold an agreed part of their output to the state at a controlled Plan price and anything above that at a negotiated price. Although the latter was still controlled, it might roughly approximate to a free market price. The dual price system was meant to facilitate a gradual increase in the role that the market played in allocating factors and products. It was also hoped that it would provide firms with incentives to increase production and productivity. This has no doubt occurred, as at the margin firms are increasingly operating in a more market-orientated system.

However, because of poor macroeconomic control and inflationary pressures in the 1980s, negotiated prices of products continued to diverge from Plan prices. Until very recently, with reforms in basic raw material prices, dual prices for products had not converged. Hence, the two-tier price system may actually have increased the irrationality of the allocation system in many sectors. Time-consuming negotiations are required to secure raw materials at prices appropriate to the output prices enterprises can receive for their output, and for achieving agreement on the Plan and negotiated prices at which output will be sold. Negotiations are typically based on personal contacts, or *guanxi*, with those in the agencies responsible for the allocation of resources. The success or failure of firms is frequently not a result of performance in the market, but this so-called *guanxi* effect (Wall 1990). The two-tier price system provides widespread opportunities for corruption. Some officials and firms with control over Plan priced outputs in high demand were able sell these goods in free markets, where they commanded significantly higher prices (Byrd 1988; Wu and Zhou 1988).

The many anomalies which persist in the two-tier system of plan and market allocation, as well as the failure to fully implement reforms in the areas of enterprise management and labour and capital markets, could well have resulted in disappointing levels of productivity growth in the second half of the 1980s. Nevertheless, in the period since the opening of the Chinese economy, many reforms have been attempted, and some have had beneficial effects. It is therefore important to determine whether the overall impact on industrial productivity growth has been positive or negative.

One of the methods of determining this impact is to ascertain the extent of total factor productivity growth in various industrial cities with different policy regimes: Xiamen, a special economic zone; Shanghai, a coastal city; and Beijing, a city which has not been given any special status but nevertheless has benefited from high levels of new investment. The case study of the special economic zone, Xiamen, is undertaken in some detail to provide an indication of the productivity performance which could be expected of Chinese industries under more liberal policy regimes.

IV. Model Specification

Various production function specifications were employed to model industry production data from Xiamen, Beijing and Shanghai including a simple Cobb-Douglas production function and the more flexible translog production function. These were used to derive the output elasticities of factors, which were then employed in the determination of total factor productivity growth in the various industrial sectors.

A generalized production function was hypothesized, which can be described as:

$$Q = f(X, \alpha) \tag{1}$$

where Q is output, X is the physical factor inputs and α is some residual factor, which we may call technical progress or factor productivity growth. Assuming initially that the appropriate functional form is an unconstrained Cobb-Douglas production function, and taking logs, Equation (1) can be expressed as:

$$\ln Q = \sum \varepsilon_i \ln X_i + T(X, t) \quad (2)$$

where ε_i is the output elasticities of factors X_i, and T(X, t) is technical progress or the total factor productivity growth coefficient. An alternative specification of the production function is the more flexible translog production function. When estimating the output elasticities from Equation (2), an unconstrained translog formulation is also estimated for comparative purposes. The results of this analysis are discussed in the following section.

Differentiating the Cobb-Douglas production function with respect to time and manipulating it gives:

$$\frac{d\ln Q}{dt} = \sum \varepsilon_i \frac{d\ln X_i}{dt} + T(X, t). \quad (3)$$

Assuming constant returns to scale, profit maximization, (i.e., the marginal revenue product of factors will equal their factor rents), and using Euler's theorem, Equation (3) can be written as:

$$\frac{d\ln Q}{dt} = \left(\sum \frac{w_i X_i}{PQ} \frac{d\ln X_i}{dt} \right) + T(X, t) \quad (4)$$

where w_iX_i/PQ is the earnings share of factor i in total output.

Total factor productivity growth can then be represented as:

$$T(X, t) = \frac{d\ln Q}{dt} - \left(\sum \frac{w_i X_i}{PQ} \frac{d\ln X_i}{dt} \right). \quad (5)$$

This is the difference between the change in the level of output over time and the change in the weighted level of inputs, where weights reflect the factor output elasticity, or factor shares of inputs.

For discreet data, the Tornqvist index approximation of total factor productivity growth exactly retrieves values from a trans-

log specification of the production function (Diewert 1976; Fuss 1977). The Tornqvist index of total factor productivity growth is given by:

$$T(X, t) = \ln Q_t - \ln Q_{t-1} - \sum 0.5\,[V_{i,t} + V_{i,t-1}]\,[\ln X_{i,t} + \ln X_{i,t-1}] \quad (6)$$

where $V_i = w_iX_i/PQ$, is the share of total output value received by factor i.

However, the use of factor shares as weights raises problems. It requires the assumptions of perfect competition in factor and goods markets and the applicability of the marginal revenue product theory of distribution. Under these conditions, the marginal revenue product of the factors are expected to equal their factor rents, and their output elasticities are expected to equal their shares in total value added. These assumptions are likely to be unacceptable in the Chinese economy, as in most other planned economies (Weitzman 1970). Hence, first estimates are made of the factor output elasticity of labour and capital in industry in Xiamen, Beijing and Shanghai (the ε_i coefficients from Equation 2), for use in the Tornqvist index estimates of total factor productivity growth.

The traditional index of total factor productivity is estimated, using the relationship, below:

$$TFP(t) = \frac{Q(t)}{\Pi\, X_i(t)^{e_i}} \quad (7)$$

where e_i is the output elasticities of factors estimated from Equation (2) above, and $X_i(t)$ is the value of factor inputs used in the production of X_i.

The level of usual factor inputs, such as labour, capital and material, may not be the only influences on total factor productivity growth. It is also likely to vary with the management techniques used by firms, proxied by ownership (O), domestic macroeconomic policy, and the public policy regime under which the firm is operating (R), which has varied over time, and the industry sector involved (S). The latter factor may be important because exposure to domestic and international competition and the rates of technological change and innovation, and the rates at which new technologies are adopted are likely to vary between industries. Also, choices of technology, proxied by the capital labour ratio (K/L), may influence the rate of total factor productivity growth.

In order to explain the sources or determinants of total factor productivity growth, a Cobb-Douglas style production function approach is used, similar to the method of Griliches (1979), Svejnar (1987), Lichtenberg and Siegel (1989) and many other empirical studies of this nature. Management style, (ownership, (O), policy regime (R) and industry sector (S), are included as separate "factors" of production in addition to capital, labour and materials.

$$Q(t) = \alpha^{\lambda t}\,\Pi X_i(t)^{\beta i}\,O(t)^{\alpha 1}\,S(t)^{\alpha 2}\,R(t)^{\alpha 3} \qquad (8)$$

where

$Q(t)$ = gross output (or net if materials are omitted from inputs);

α = a constant;

λ = a residual Hicks neutral technical change parameter;

$X_i(t)$ is factor inputs where,

$X_1(t)$ = K(t) the stock of physical capital;

$X_2(t)$ = L(t) labour input;

$X_3(t)$ = M(t) material inputs (including energy);

$O(t)$ = management system, proxied by ownership;

$S(t)$ = industrial sector, capturing industry specific rates of accumulation of technological knowledge and exposure to international competition;

$R(t)$ = domestic policy regime, which has varied over time;

β_i = factor output elasticity of factor i;

$\alpha 1, \alpha 2, \alpha 3$ = output elasticity of the factors of management style, industry specific technical change and international exposure and domestic policy regime.

By taking logs of Equation (8), differentiating with respect to time, assuming constant returns to scale, re-parameterization allows growth in total factor productivity to be represented as:

$$DTFP = \lambda + \alpha_1\,O(t) + \alpha_2\,S(t) + \alpha_3\,R(t) + e \qquad (9)$$

where λ is the rate of residual, unexplained, technical change; $\alpha 1$, $\alpha 2$, $\alpha 3$ are the output elasticities for variations in ownership, industrial sector and policy regime and e is a normally distributed disturbance term.

V. Xiamen Industrial Productivity Performance

If Xiamen industry has experienced improved total factor productivity growth, there are several possible reasons this may have happened.

- The structure of Xiamen industry may well have changed due to the opening of the economy to international trade, the availability of infrastructure and the entry of foreign and private investors with knowledge in particular industries.
- Changes in the ownership structure of industry in Xiamen may also have impacted on productivity growth. There has been a strong growth in collectively owned firms throughout the reform period and a rapid growth of joint foreign-Sino owned ventures after their introduction in 1984. It may be expected that the incentive structure for workers and managers in such firms could have encouraged higher productivity. The study will therefore assess whether factor productivity growth has varied significantly between firms with different ownership (state, collective, or joint venture) and whether the relative growth of these sectors helps to explain overall total factor productivity growth.

- The introduction of the special economic zone itself may have improved total factor productivity growth. Productivity in the period 1984-1989 is compared with that in the period 1979-1984 to assess whether the zone's creation has had any significant impact on total factor productivity growth in the industrial sector.
- Inappropriate choice of technology in new enterprises, due to poor project analysis, may have impaired productivity growth in some firms. Variables such as the capital intensity of industry sectors are used as regressors with respect to the rate of total factor productivity growth, to determine if there is any significant relationship between the two.
- The export orientation of different industrial sectors may have influenced total productivity growth. As data have only been published on the export orientation of industry in Xiamen for one year so far, 1988, a time series analysis of this relationship is not yet possible. However, a cross-sectional analysis could possibly be undertaken (Yang 1991).
- Finally, it is possible that China's stop-go macroeconomic policies, which have caused major drops in production in some years, have affected total factor productivity growth. Their impact will also be assessed using dummy variables for years when macroeconomic policy settings were tight.

Basic industry data on Xiamen are given in Tables 1.1 and 1.2 in Appendix 1. These tables include data on the levels of real net output and employment, the deflated value of capital stock, and estimated changes in labour and capital productivity and capital intensity by ownership type and sector. The study employs annual data for Xiamen industry for 1979-1989, drawn from the relevant Xiamen Almanacs. This data is disaggregated and cross-tabulated by ownership and industry sector. Data is disaggregated into 10 manufacturing industry sectors: metallurgical products; chemicals; machinery; construction materials; forest products and furniture; food products; textiles; garments (sewing); leather products and paper products. Although since 1985, more disaggregated data are available for manufacturing industries, to facilitate an analysis over the 10 to 12 years since reform commenced, it is necessary to retain the more aggregated categorisation available prior to 1985.

Chinese capital stock data is an aggregation of net investment undertaken each year valued at current prices for each year (Chen et al. 1988b). It is impossible to use such data for productivity studies, as there is no correction for the impact of inflation. To overcome this problem, capital stock data was deflated to 1980 values using the disaggregated index of capital stock estimated at the Institute of Quantitative Economics, CASS, Beijing.[2] The newly constructed capital stock data are given in Table 4.1 in Appendix 4.

Compilation of these indexes involved breaking down the investment undertaken in each of the industrial sectors into 147 components, deflating each of these components using State Statistical Bureau data and using these deflated components to form a weighted price index for capital investment for each sector. This was then used to deflate each year's investment data to 1980 prices. The undeflated investment undertaken each year was then subtracted from capital stock data, the newly deflated investment data added back in, and depreciation subtracted, to obtain consistently compiled real capital stock data (Chen et al. 1988b).

In addition, it is common for Chinese statistics on productive enterprises' capital stocks to include assets which are not directly productive, but are instead related to worker welfare, such as housing, clinics and childcare centres. At least one study of Chinese productivity growth found that revaluation of capital stock to take account of these factors raised the rate of total factor productivity growth in Chinese industry to modestly positive levels (Chen et al. 1988a).

There has been a rapid growth of output, employment and investment in Xiamen industry over the past 10 years. The constant (1980) yuan value of Xiamen's industrial output increased 306 per cent, from 292 million yuan in 1980 to 1.186 billion yuan in 1988. State industry's output increased 181 per cent from 234 million yuan to 657 million yuan. Collective industry's output rose 132 per cent to 134 million yuan. In the first five years of their operation, the output of joint ventures rose from 6 to 396 million yuan. Preliminary data for 1989, shown in Table 1.1 in Appendix 1, indicate that joint venture output soared to 794 million yuan in 1989. This was slightly higher than the output of all state-owned firms in Xiamen for that year, 779.6 million yuan.[3]

This growth was achieved with massive injections of capital and a more modest growth in the industrial workforce. The capital stock increased 385 per cent from 356 million yuan, in 1980 to 1.7 billion yuan in 1989 (both in 1980 prices). Employment, on the other hand, rose only 117.7 per cent over the same period, from 83,500 to 181,200 workers. The capital intensity of production techniques therefore increased by 230 per cent. As a consequence, output per worker rose by 186 per cent, while output per unit of capital employed (the capital output ratio) rose by 12.9 per cent, over the 10 year period. The adoption of capital-intensive techniques was most evident in the joint-owned firms, which were 57 per cent more capital-intensive than the average firm. High capital intensity was much less common in the collective sector, which were 56 per cent more labour-intensive than the state industrial enterprises in Xiamen, and more than eight times more labour-intensive than the joint ventures.

Over the reform period, all industrial sectors except construction and leather products became more capital-intensive. The trend towards capital intensity was particularly marked in the chemicals, textiles and garments industries. However, the performances of individual industrial sectors varied widely, with several, like construction products, food products, machinery, metallurgy and printing and paper, showing strong growth in output per unit of capital and labour and others, like leather products, showing a strong decline in both.

VI. Estimation of Output Elasticities of Productive Factors

Panel data of cross-section (by industry and ownership) and time series data were used to increase estimate factor output elasticities, the ε_i estimated using Equation (2). The Xiamen input and output data were disaggregated by industry, and within each industry, by ownership type. Hence, to construct the panel data, for each ownership type, data were pooled for the 10 industries. Similarly, for each industry, panel data were constructed from time series and cross-section data on that industry, pooled for the three ownership types. This procedure effectively expanded the data set from 10 to 25 observations for the industry data and from 10 to 100 observations for the firm ownership data.[4] Tests were undertaken to determine if this procedure was valid, revealed an absence of heteroscedasticity in the pooled data.

Initially, unconstrained factor output elasticities (ε_i), were estimated for a simple two factor Cobb-Douglas production function. Subsequently, these elasticities were re-estimated imposing a constant returns to scale constraint. F-ratio tests were unable to reject the hypothesis that the Cobb-Douglas production function was subject to constant returns to scale. In addition, the constrained Cobb-Douglas formulation was tested against the more flexible unconstrained translog specification, and again, the F-ratio test failed to reject the hypothesis that the constant returns to scale Cobb-Douglas production function was the appropriate specification (Table 2.1 in Appendix 2).

Lin (1991) also undertook F-ratio tests to determine the appropriate functional form for a production function fitted to national level industrial data which was compiled by Chen et al. (1988a). Lin's tests indicated that a constant returns to scale Cobb-Douglas production function is also the appropriate specification for this national-level production data. Chen et al. also obtained this result, although they continued to quote the results of both the Cobb-Douglas and translog specifications throughout the presentation of their results.

The output elasticities of capital and labour in Xiamen industry, estimated from a constrained Cobb-Douglas production function, by ownership type and sector are compared to the factor shares actually received by labour and capital in Tables 2 and 3. For industry overall, the output elasticity for labour was found to be 0.4, while that for capital was 0.6. The output elasticity of labour in the state-owned sector was considerably lower than in the collective and joint-venture sectors, possibly reflecting overmanning in state industries.

A comparison of these estimates with those calculated for the whole of Chinese industry by Chen et al. (1988a) indicates the experience of Xiamen industry has been quite similar to that of the rest of Chinese industry. Chen et al. estimated that the output elasticity of capital varied from 0.542 to 0.722 (depending on whether a Cobb-Douglas or translog production function, respectively, was used). The output elasticity of labour was between 0.458 and 0.278, for these two production function specifications, respectively.

Inflation in capital goods prices since 1980 offers a possible reason for the divergence in the capital output elasticities in the different sectors, and in particular the negative capital productivity in some sectors. Jefferson (1990) maintained that large increases in the price of capital goods have not been matched by increases in the productivity of these capital goods. Using 1985 cross-section data on the iron and steel industry, Jefferson also found that the greater the proportion of technical renovation capital in total investment undertaken by particular firms, the higher the output elasticity of capital. He found that the output elasticity of basic construction capital was not significantly different from zero (Jefferson 1990). Such factors could well be driving the observed differences in capital productivity in different sectors.

Table 2 Factor output elasticity (OE) and factor shares for Xiamen industry by ownership, 1979-1988

	OE capital	Capital share	OE labour	Wage share	OE capital	Capital share	OE labour	Wage share
	Total				State firms			
1979	0.600	0.788	0.400	0.212	0.783	0.790	0.217	0.210
1980	0.600	0.749	0.400	0.251	0.783	0.754	0.217	0.246
1981	0.600	0.762	0.400	0.238	0.783	0.759	0.217	0.241
1982	0.600	0.757	0.400	0.243	0.783	0.758	0.217	0.242
1983	0.600	0.742	0.400	0.258	0.783	0.738	0.217	0.262
1984	0.600	0.749	0.400	0.251	0.783	0.746	0.217	0.254
1985	0.600	0.762	0.400	0.238	0.783	0.763	0.217	0.237
1986	0.600	0.751	0.400	0.249	0.783	0.748	0.217	0.252
1987	0.600	0.702	0.400	0.298	0.783	0.637	0.217	0.363
1988	0.600	0.689	0.400	0.311	0.783	0.598	0.217	0.402
	Collective firms				Joint firms			
1979	0.339	0.778	0.661	0.222	0.000	0.000	0.000	0.000
1980	0.339	0.733	0.661	0.267	0.000	0.000	0.000	0.000
1981	0.339	0.774	0.661	0.226	0.000	0.000	0.000	0.000
1982	0.339	0.755	0.661	0.245	0.000	0.000	0.000	0.000
1983	0.339	0.756	0.661	0.244	0.000	0.000	0.000	0.000
1984	0.339	0.761	0.661	0.239	0.419	0.423	0.581	0.577
1985	0.339	0.647	0.661	0.353	0.419	0.905	0.581	0.095
1986	0.339	0.632	0.661	0.368	0.419	0.867	0.581	0.133
1987	0.339	0.594	0.661	0.406	0.419	0.886	0.581	0.114
1988	0.339	0.569	0.661	0.431	0.419	0.873	0.581	0.127

Table 3 Factor output elasticity (OE) and factor shares by industry in Xiamen, 1979-1988

	OE capital	Capital share	OE labour	Wage share	OE capital	Capital share	OE labour	Wage share
	Chemicals				Construction			
1979	0.620	0.885	0.380	0.115	0.380	0.835	0.620	0.165
1980	0.620	0.863	0.380	0.137	0.380	0.764	0.620	0.236
1981	0.620	0.869	0.380	0.131	0.380	0.802	0.620	0.198
1982	0.620	0.873	0.380	0.127	0.380	0.778	0.620	0.222
1983	0.620	0.867	0.380	0.133	0.380	0.857	0.620	0.143
1984	0.620	0.841	0.380	0.159	0.380	0.866	0.620	0.134
1985	0.620	0.752	0.380	0.248	0.380	0.750	0.620	0.250
1986	0.620	0.719	0.380	0.281	0.380	0.725	0.620	0.275
1987	0.620	0.797	0.380	0.203	0.380	0.631	0.620	0.369
1988	0.620	0.800	0.380	0.200	0.380	0.538	0.620	0.462
	Textiles				Forest products and furniture			
1979	0.637	0.819	0.363	0.181	0.135	0.891	0.865	0.109
1980	0.637	0.759	0.363	0.241	0.135	0.861	0.865	0.139
1981	0.637	0.805	0.363	0.195	0.135	0.870	0.865	0.130
1982	0.637	0.730	0.363	0.270	0.135	0.906	0.865	0.094
1983	0.637	0.640	0.363	0.360	0.135	0.918	0.865	0.082
1984	0.637	0.617	0.363	0.383	0.135	0.879	0.865	0.121
1985	0.637	0.791	0.363	0.309	0.135	0.723	0.865	0.277
1986	0.637	0.618	0.363	0.382	0.135	0.634	0.865	0.366
1987	0.637	0.580	0.363	0.420	0.135	0.606	0.865	0.394
1988	0.637	0.618	0.363	0.382	0.135	0.603	0.865	0.397
	Food products				Metallurgy			
1979	0.944	0.919	0.056	0.081	0.676	0.554	0.324	0.446
1980	0.944	0.905	0.056	0.095	0.676	0.404	0.324	0.596
1981	0.944	0.908	0.056	0.092	0.676	0.490	0.324	0.510
1982	0.944	0.907	0.056	0.093	0.676	0.549	0.324	0.451

Table 3 (Continued)

1983	0.944	0.892	0.056	0.108	0.676	0.602	0.324	0.398
1984	0.944	0.908	0.056	0.092	0.676	0.634	0.324	0.366
1985	0.944	0.892	0.056	0.108	0.676	0.824	0.324	0.176
1986	0.944	0.887	0.056	0.113	0.676	0.869	0.324	0.131
1987	0.944	0.879	0.056	0.121	0.676	0.832	0.324	0.168
1988	0.944	0.879	0.056	0.121	0.676	0.826	0.324	0.174
	Machinery				Paper products			
1979	0.135	0.760	0.865	0.240	0.452	0.880	0.548	0.120
1980	0.135	0.767	0.865	0.232	0.452	0.857	0.548	0.143
1981	0.135	0.780	0.865	0.220	0.452	0.854	0.548	0.146
1982	0.135	0.807	0.865	0.193	0.452	0.818	0.548	0.182
1983	0.135	0.795	0.865	0.205	0.452	0.780	0.548	0.220
1984	0.135	0.812	0.865	0.188	0.452	0.773	0.548	0.227
1985	0.135	0.886	0.865	0.114	0.452	0.774	0.548	0.226
1986	0.135	0.883	0.865	0.118	0.452	0.786	0.548	0.214
1987	0.135	0.830	0.865	0.170	0.452	0.678	0.548	0.322
1988	0.135	0.822	0.865	0.178	0.452	0.638	0.548	0.632
	Garments				Leather products			
1979	-0.042	0.756	1.042	0.244	0.627	0.850	0.373	0.150
1980	-0.042	0.748	1.042	0.252	0.627	0.876	0.373	0.124
1981	-0.042	0.662	1.042	0.237	0.627	0.792	0.373	0.208
1982	-0.042	0.667	1.042	0.333	0.627	0.739	0.373	0.260
1983	-0.042	0.657	1.042	0.343	0.627	0.762	0.373	0.238
1984	-0.042	0.712	1.042	0.288	0.627	0.816	0.373	0.184
1985	-0.042	0.582	1.042	0.418	0.627	0.563	0.373	0.437
1986	-0.042	0.474	1.042	0.526	0.627	0.539	0.373	0.461
1987	-0.042	0.286	1.042	0.714	0.627	0.523	0.373	0.476
1988	-0.042	0.323	1.042	0.687	0.627	0.313	0.373	0.687

Tables 4 and 5 attempt to show whether economic reform has affected allocative efficiency in Xiamen industry. This is measured by the extent of divergence of the factor shares and the output elasticity of factors. Neoclassical price theory anticipates that, in a perfectly competitive market, the ratio of factors' marginal products will equal the ratio of their factor rents, which will also equal the elasticity of substitution between the factors. This is equivalent to the equality of the ratio of factor shares (labour share, ws : capital share, ks) with the ratio of factor output elasticities, $(\varepsilon_l/\varepsilon_k)$. Hence in a perfectly competitive market,

$$\frac{\varepsilon_l}{\varepsilon_k}=\frac{ws}{ks}$$

$$\varepsilon_l ks - \varepsilon_k ws = 0. \qquad (10)$$

Table 4 Economic efficiency[1] of Xiamen industry by ownership, 1979-1988

	Total	State	Collective	Joint
1979	-0.187	-0.007	-0.440	0.000
1980	-0.149	0.030	-0.395	0.000
1981	-0.161	0.025	-0.435	0.000
1982	-0.157	0.025	-0.416	0.000
1983	-0.142	0.045	-0.418	0.000
1984	-0.149	0.037	-0.423	-0.005
1985	-0.161	0.020	-0.309	-0.487
1986	-0.150	0.035	-0.293	-0.448
1987	-0.102	0.146	-0.256	-0.468
1988	-0.089	0.185	-0.231	-0.454

Note: (1) Difference between the ratio of marginal productivity of capital and labour and their factor shares. A figure of zero implies economic efficiency in the remuneration and allocation of factors.

Table 5 Economic efficiency and inefficiency[1] of Xiamen industry by industry, 1980-1988

	Chemicals	Construction products	Forest products	Food products	Metallurgy
1980	-0.243	-0.384	-0.726	0.039	0.272
1981	-0.250	-0.423	-0.735	0.036	0.186
1982	-0.253	-0.398	-0.771	0.037	0.127
1983	-0.248	-0.477	-0.783	0.052	0.075
1984	-0.221	-0.486	-0.744	0.035	0.042
1985	-0.133	-0.370	-0.588	0.052	-0.147
1986	-0.099	-0.346	-0.499	0.057	-0.193
1987	-0.177	-0.251	-0.471	0.064	-0.155
1988	-0.181	-0.159	-0.468	0.065	-0.150
	Machinery	Paper products	Textiles	Leather products	Garments
1980	0.422	-0.405	-0.122	-0.248	-0.788
1981	0.409	-0.402	-0.167	-0.164	-0.803
1982	0.382	-0.366	-0.093	-0.112	-0.708
1983	0.393	-0.329	-0.002	-0.134	-0.697
1984	0.377	-0.322	-0.020	-0.189	-0.752
1985	0.303	-0.323	-0.053	0.064	-0.622
1986	0.305	-0.334	-0.019	0.088	-0.515
1987	0.359	-0.226	0.057	0.104	-0.326
1988	0.367	-0.186	0.020	0.314	-0.363

Note: (1) Difference between the ratio of the output elasticity of capital and labour and their factor shares.

Tables 4 and 5 give estimates of the expression in Equation (10) as a measure of the allocative efficiency of Xiamen industry. An estimate close to zero indicates a high level of allocative efficiency, with the ratio of output elasticities of factors close to the ratio of factor shares.

While overall, total Xiamen industry appears to exhibit good allocative efficiency, with the estimated expression in Equation (10) close to zero in most years, estimates disaggregated by firm ownership type and sector indicate that there is a quite inefficient allocation of factors in many sectors.

Interestingly, in the state-owned sector, the share of value added claimed by factors is not greatly different from their output elasticities at the beginning of the reform period. In recent years, however, there has been a marked tendency for the wage share in the state-owned sector to exceed labour's output elasticity. This may possibly be a result of the bonus leap-frogging discussed previously, and the capacity of workers to pressure management for a greater share of retained earnings. In the collective and joint-foreign owned firms, the output elasticity of labour is considerably greater than the share it receives of value added at the commencement of the reform period. However, this divergence has narrowed in recent years, as the wage share in total value added has been increasing in collective and joint-foreign owned firms. In fact, the wage rates in the joint-venture firms substantially exceed those in state-owned ones, even though the wage share in the latter is higher (Lin 1991).

The divergence of factor productivity and wage shares in the two non-state sectors may be explained by the tendency of joint-venture and collective firms to pay labour at prevailing wage rates, which were in the early 1980s determined by productivity in the still dominant state-owned sector, rather than on the basis of labour productivity in the joint-venture and collective firms themselves. Also, these results may indicate that the omission of entrepreneurial skill as a factor may introduce errors in calculating output elasticities of labour and capital in the private sector.

Table 5 compares factors' output elasticities and their factor shares for the 10 major industrial sectors. There is a reasonably close correspondence between these two for the chemicals, food products, machinery, metallurgy, textiles and leather goods industries, but a considerable divergence in the construction products, furniture and forest products, paper and printing and garments industries. However, the most striking feature of the data in Table 5 is that, in almost every sector, allocative efficiency has improved substantially during the reform period. It seems highly likely that this improvement in allocative efficiency has occurred as a result of the economic reform process.

VII. Total Factor Productivity Growth

Tornqvist indexes of total factor productivity growth were constructed from 1980-1989 data for all Xiamen industries in each of the different ownership categories — state, collective and joint venture — and each of the major industry sectors. For the reasons discussed above, the constrained Cobb-Douglas production function estimates of factor output elasticities, rather than factor shares, are employed in constructing these Tornqvist indexes of total factor productivity growth. The results of this estimation are given in Tables 6 and 7 below. However, for comparative purposes, total factor productivity indexes are also estimated using the traditional factor shares method (Tables 3.1 and 3.2 in Appendix 3).

Table 6 shows the estimated indexes of total factor productivity growth for each of the different categories of ownership over the period 1981-1988. Estimates of total factor productivity growth in Table 6 are used to calculate the indexes of total productivity for Xiamen industry in Table 7. These indexes are constructed by employing the normal convention of designating total factor productivity in the commencing year of the analysis as unity.[5]

Table 6 indicates that on average overall total factor productivity growth in Xiamen's industrial sector appears to have been quite high, at 5.7 per cent per annum over the eight year period to 1988. The average performance for the reform period is lowered by the fact that in two of the nine years, 1986 and 1987, there is actually negative total factor productivity growth. That is, the weighted growth of inputs exceeds the growth of output in these years. Table 7 indicates that the index of total factor productivity rises 46 per cent between 1980 and 1988.

Table 6 Total factor productivity growth performance(1) of Xiamen industry by ownership type, 1981-1988 (%)

	Total	State	Collective	Joint
1981	6.09	6.75	6.21	0.00
1982	4.47	7.04	-6.37	0.00
1983	1.52	0.41	7.50	0.00
1984	16.57	19.16	7.99	0.00
1985	18.18	5.53	15.52	121.25
1986	-7.83	-16.33	0.56	-19.97
1987	-7.96	-8.38	-1.69	-30.35
1988	14.96	16.33	16.67	8.38
Av 80-83	**4.0**	**4.74**	**2.45**	**NA**
Av 84-88	**6.78**	**3.26**	**7.81**	**15.86**
Av 80-88	**5.7**	**3.8**	**5.8**	**NA**

Note: (1) Estimated total factor productivity weights.

Table 7 Indexes of total factor productivity growth of Xiamen industry by ownership, 1980-1988

	Total	State	Collective	Joint
1980	1.000	1.000	1.000	NA
1981	1.060	1.067	1.062	NA
1982	1.105	1.137	0.998	NA
1983	1.120	1.142	1.073	NA
1984	1.286	1.333	1.153	1.000
1985	1.468	1.388	1.308	1.657
1986	1.389	1.225	1.314	1.457
1987	1.310	1.141	1.297	1.154
1988	1.460	1.305	1.464	1.238

Productivity of state firms improves quite strongly, averaging 3.8 per cent per annum over the period, from 1981 to 1988. The index of total factor productivity in the state-owned sector increases by 30.5 per cent over the nine years from 1980 to 1988. However, in 1985, prior to the 1987 recession, the total factor productivity index in the state sector has risen to 1.39, before falling to 1.14 in 1987. That is, a 39 per cent increase in productivity has been achieved between 1980 and 1985, but by 1987 many of these gains have been dissipated and productivity has fallen to its 1983 level.

The collective firms achieve somewhat higher average productivity growth, 5.8 per cent per annum, over the same period. The index of total factor productivity of the collective sector rises 46 per cent over the nine years to 1988. The rather erratic total factor productivity growth of the joint-venture firms can be explained by the fact that from 1984 to 1986 there is only a relatively small number of newly established joint ventures in Xiamen, and these are undertaking lumpy investments. However, over their five years of operation, the joint-venture firms have achieved remarkable productivity growth, averaging 15.9 per cent per annum. As this sector has become more significant in Xiamen's economy, its strong performance has made a significant impact on the overall productivity performance of Xiamen's industrial sector. The index of total factor productivity of the joint sector grows by 23 per cent in three years.

Hence, the productivity growth of non-state industry appears to have increased since the SEZ was established in 1984. In the period 1980 to 1983, its productivity grows at 4 per cent per annum, while after 1984 the annual growth of total factor productivity rises to 6.78 per cent per annum. The establishment of joint-foreign owned firms after 1984, with their higher productivity growth, contributes significantly to this improvement, but the collective sector also records higher total factor productivity growth after 1984.

Tables 3.1 and 3.2 in Appendix 3 give estimates of total factor productivity growth in Xiamen industry, using actual factor shares of labour and capital as the weights in the Tornqvist index.[6] Using factor shares as the weights for estimating Tornqvist indexes of total factor productivity growth, the productivity performance of Xiamen industry appears to be somewhat lower than if estimated factor output elasticities are used. The state-owned sector appears to do slightly better using this methodology, and the collective and particularly the joint-owned sectors worse than when directly estimated marginal productivities are employed. However, theoretically, there is no justification for using factor shares as proxies for the output elasticity of factors unless there are perfect or close to perfectly competitive factor and goods markets operating.[7]

Table 8 gives the total factor productivity growth performance in the eight major sectors of Xiamen industry. Once again, estimates are made using Tornqvist indexes employing weights equal to the directly estimated output elasticity of factors. Table 9 examines the indexes of total factor productivity of the 10 industrial sectors. The indexes of total productivity of all industrial sectors except chemicals, rose over the nine years. In the metallurgy sector, total factor productivity rose by an astounding 408 per cent, the machinery sector's rose by 242 per cent, while in the textiles sector total factor productivity rose by a more modest 17 per cent. The leather sector apparently suffered a 62 per cent drop in productivity in 1981, but this may well indicate an error in the data for that year. Hence the index of factor productivity for leather is calculated beginning in 1981.

Table 8 Total factor productivity growth performance[(1)] of Xiamen industry by sector, 1981-1989 (%)

	Chemicals	Construction products	Forest products	Food products	Metallurgy
1981	-8.35	21.87	7.01	5.24	-2.69
1982	13.68	-1.24	44.35	14.47	12.85
1983	4.39	54.12	20.16	0.97	17.78
1984	-0.57	23.65	-26.77	24.54	-15.84
1985	-2.44	-25.13	-50.82	6.70	126.99
1986	2.94	1.54	-18.41	-3.06	46.87
1987	-24.41	-28.82	2.63	-17.63	-17.74
1988	12.21	10.89	24.57	11.10	69.67
1989	-6.13	-37.67	-35.25	-8.06	0.56
Av 80-83	**3.24**	**24.92**	**23.99**	**6.89**	**9.31**
Av 84-88	**-2.45**	**-3.58**	**-13.76**	**4.33**	**41.99**
Av 80-89	**-0.96**	**2.13**	**-3.56**	**3.81**	**26.49**
	Paper products	Textiles	Garments	Leather products	Machinery products
1981	6.37	27.48	8.71	-62.85	0.084
1982	-10.00	-24.17	-25.87	-18.69	0.239
1983	-12.72	-19.51	10.11	15.95	0.057
1984	10.43	13.01	28.02	30.67	0.046
1985	30.96	18.65	-16.81	-38.27	0.758
1986	13.27	-14.14	-2.92	14.56	0.139
1987	-37.89	-22.25	-10.81	4.00	-0.291
1988	11.85	28.55	13.26	-18.94	0.126
1989	22.71	-30.22	40.19	15.28	0.267
Av 80-83	**-5.45**	**-5.40**	**-2.35**	**-21.86**	**0.127**
Av 84-88	**5.72**	**4.76**	**2.15**	**-1.59**	**0.156**
Av 80-89	**3.89**	**-2.51**	**4.88**	**-6.47**	**0.158**

Note: (1) Estimated total factor productivity weights.

Table 9 Indexes of total factor productivity growth of Xiamen Industry by industry, 1980-1989

	Chemicals	Construction products	Forest products	Food products	Metallurgy
1980	1.000	1.000	1.000	1.000	1.000
1981	0.917	1.219	1.070	1.052	0.973
1982	1.053	1.206	1.514	1.197	1.102
1983	1.097	1.748	1.720	1.207	1.279
1984	1.092	1.984	1.452	1.452	1.121
1985	1.067	1.733	0.944	1.519	2.391
1986	1.097	1.748	0.760	1.489	2.860
1987	0.853	1.460	0.786	1.312	2.682
1988	0.975	1.569	1.032	1.423	3.379
1989	0.975	1.569	1.277	1.534	4.075
	Paper products	Textiles	Garments	Leather products	Machinery products
1980	1.000	1.000	1.000	1.000	1.000
1981	1.064	1.275	1.087	0.999	1.083
1982	0.964	1.033	0.828	0.813	1.322
1983	0.837	0.838	0.930	0.942	1.380
1984	0.941	0.968	1.210	1.231	1.424
1985	1.250	1.155	1.042	0.759	2.183
1986	1.383	1.013	1.012	0.870	2.322
1987	1.004	0.791	0.904	0.905	2.031
1988	1.123	1.076	1.037	0.734	2.157
1989	1.241	1.362	1.170	0.846	2.424

The apparently rapid productivity growth of the machinery sector may be explained by the inflation of machinery prices since 1980, noted in Jefferson (1990). Although this should be corrected for by the sector specific price indexes used to deflate output data, it is unlikely that these indexes could capture the effects of spurious product reclassification. The practice of firms claiming that they have produced a new product, when in fact it is only a slight modification of an old one, has apparently been widely used by firms to increase their prices above state controlled levels. Hence the rapid increase in productivity in this (and possibly the metallurgy sector) could be partially explained by this practice.[8]

VIII. Sources of Total Factor Productivity Growth

In an attempt to determine the sources of productivity growth and the causes of poor productivity performance, where it occurred, pooled data on total factor productivity growth was regressed on a range of explanatory and dummy variables, as outlined in Equation (9). Regressions were run on Tornqvist indexes of annual total factor productivity growth, constructed from pooled cross section and time series data for each industry, and for each form of firm ownership. The explanatory variables included vectors of dummy variables constructed for each of the different ownership types and industry sectors, the years of the different policy regimes (prior to and since 1984, when the special economic zone was established in Xiamen) and macroeconomic settings, (the recession year, 1989). In addition, the capital intensity of sectors and industries was included as a potential explanatory variable of total factor productivity growth.

The results of this estimation are given in Table 10. The dummy for the textiles industry was dropped from the estimation because its productivity growth was closest to zero. Hence the coefficients reflect the productivity performance of each sector relative to that of the textiles. The regression results indicated that if a firm was collectively or joint-foreign owned, it was likely to have considerably higher productivity growth than if it were a state-sector firm. The expected TFP growth, (in excess of the textiles sector's) of the collective- and joint-owned sectors was 3.2 and 16.3 per cent respectively, while that of the state sector was 2.8 per cent per annum. However, the low t-statistics indicate that none of the coefficients on the ownership dummies was statistically significant.

Table 10 Sources of TFP growth of Xiamen industry, 1980-1989

Variable	Coefficient	t-stat
Ownership[1]		
State firms	0.028	0.228
Collective firms	0.032	0.296
Joint firms	0.163	0.920
Industries		
Chemicals	-0.040	-0.305
Construction	0.045	0.394
Forest products	-0.015	-0.136
Food processing	-0.016	-0.132
Machinery	0.180	1.659
Metallurgy	0.307	1.522
Paper and printing	-0.056	0.627
Garments	0.068	-0.340
Leather products	-0.044	-0.146
Capital labour ratio	-0.020	-0.185
SEZ policy 1984-1988	0.009	-0.146
Macro policy (1989)	-0.173	-1.840

Note: (1) The base case is the textile sector productivity growth.
$R^2 = 0.129$; DW Stat = 2.35.

Similarly, while the total factor productivity performance of the different industrial sectors generally reflects the findings in Table 7, only the coefficients for the metallurgy and machinery industries, which experienced very high total factor productivity growth, were significant at even the 12 per cent confidence limit.

Among the other explanatory variables, the capital intensity of techniques employed, proxied by the capital labour ratios of the sectors concerned, had a small negative coefficient, indicating that the capital intensity of production techniques may have had a negative influence on productivity growth. On the other hand, the dummy variable constructed to capture policy regime changes associated with the introduction of the special economic zone in 1984 had a small positive coefficient, equivalent to a 0.9 per cent increase in productivity growth. However, once again, neither of these coefficients was significant. The dummy variable constructed to reflect the tight macroeconomic settings of 1989 was negative, equivalent to a 17 percentage point drop in productivity and was highly significant.

Hence, the major influences on total factor productivity growth in Xiamen industry appear to be the micro and macroeconomic policy regimes operating in Xiamen and China as a whole. The establishment and growing importance of new forms of firm ownership, foreign joint ventures and collectively owned firms, has obviously improved the overall productivity performance of Xiamen industry. The increasing relative role of these higher productivity growth sectors appears to be the main reason for the improved overall productivity performance in Xiamen industry since 1984.

From the data available, it is difficult to determine whether any of the improved productivity performances of collective and foreign owned firms since 1984 was a result of new technologies adopted in the huge wave of investment experienced in Xiamen. However, the limited evidence available regarding the impact of adopting more capital-intensive technologies indicates that they may not have had a positive influence on total factor productivity growth. Possible explanations for this small negative influence may well be the inflation in capital goods prices, discussed previously or the failure to undertake adequate financial and economic analyses of new investment proposals as a result of the soft budget constraint on state owned firms.

The extent to which the establishment of the special economic zone in itself has helped improve factor productivity will also be examined in the following sections, by comparing the performance of Xiamen with that of Shanghai, one of the coastal cities. Beijing, which did not benefit from these preferential policy regimes, is used as a control.

The increasing openness of the Xiamen economy could well have had a beneficial impact on productivity growth in the export sector, or on the Xiamen economy in general, as has been found in studies of some other countries (including Nishimizu and Page 1986; Krueger 1978, 1983; Tyler 1981; Feder 1983).

Unfortunately, data on the destination of output from the various industrial sectors in Xiamen have only been made available since 1988, and changes in their export orientation over time cannot therefore be compared with their productivity growth.

IX. Sources of Industrial Output Growth in Xiamen

The sources of industrial output growth in Xiamen industry are disaggregated in Table 11. Total factor productivity for industry overall increased 12 per cent between 1980 and 1983, or an average of 3 per cent per annum (see Table 7). Hence, of the 26.75 per cent growth in real industrial value added achieved between 1980 and 1983, 14.7 per cent could be attributed to the growth in labour, and capital inputs growth in total factor productivity was a substantial 12 per cent over four years, (3 per cent per annum), which represented 45 per cent of the total growth. Of the growth due to the increased use of input factors, 32.5 per cent was due to increased capital stock and only 13.5 per cent to the increased size of the workforce employed.

Table 11 Sources of growth of Xiamen industry, 1980-1988 (%)

	Percentage growth			Contribution to growth from	
	Output	Labour	Capital	Factor inputs	TFP
Total industry					
Percentage growth 1980-1983	26.75	9.04	14.57	14.67	12.08
Average annual growth	6.7	2.3	3.6	3.7	
Percentage of growth	100.00	13.52	32.69	54.84	45.16
Growth 1984-1988	162.20	39.16	199.51	128.28	33.92
Average annual growth	32.4	7.8	39.9	25.7	6.8
Percentage of growth	100.00	9.11	69.93	79.09	20.91
State enterprises					
Percentage growth 1980-1983	27.59	11.38	10.51	10.70	14.21
Average annual growth	6.9	2.8	2.7	2.1	2.8
Percentage of growth	100.00	16.50	22.85	48.52	51.48
Growth 1984-1988	78.88	18.41	108.00	62.58	16.30
Average annual growth	15.8	3.7	21.6	12.5	3.3
Percentage of growth	100.00	3.60	75.66	79.33	20.67
Collective enterprises					
Percentage growth 1980-1983	23.33	4.69	36.67	15.98	7.35
Average annual growth	2.6	1.2	9.17	4.00	1.84
Percentage of growth	100.00	8.05	94.32	68.51	31.49
Growth 1984-1988	69.98	11.37	55.04	30.92	39.06
Average annual growth	14.0	2.3	11.01	6.2	7.8
Percentage of growth	100.00	15.1	29.8	44.19	55.81
Joint enterprises					
Growth 1984-1988	5879.64	947.05	9989.04	5800.33	79.32
Average annual growth	1175.9	189.4	1997.8	1160.1	1.5
Percentage of growth	100.00	11.40	87.25	98.65	1.35

In the period from 1984 to 1988, the growth in industrial output accelerated considerably, by 162 per cent over the five years, and over this period the absolute contribution of productivity growth to this total increased to 32.4 percentage points, or 6.8 percentage points per annum. However, the relative contribution of TFP growth was swamped in this huge growth of factor inputs, and its relative contribution to total growth declined to 21 per cent. The growth of capital assets contributed a huge 70 per cent of total growth and labour's contribution declined to only 9.1 per cent of total growth. The situation in the state sector was very similar to this overall position, except that after 1983 labour growth contributed an even lower proportion of total output growth, 3.6 per cent, and capital a higher proportion, 75.7 per cent.

In collective sector firms, productivity growth contributed a substantially higher proportion of total output after 1983, 55.8 per cent of output, than either of the other two sectors. In joint enterprises, although the relative contribution of TFP growth was smaller, only 1.35 per cent, its absolute contribution, 15.9 per cent per annum, was much higher than for the state or collective sectors.

X. Beijing's Industrial Output and Factor Productivity Growth

In order to compare the performance of Xiamen's industrial sector with that of other industrial areas in China, output and productivity growth in the Beijing and Shanghai state-owned industrial sectors have also been analysed. Data were disaggregated for seven major sectors: chemicals, construction materials, machinery and metal products, furniture and forest products, food beverages and tobacco products, textiles and paper. Unfortunately, separate data on collective- and joint-owned firms were not available, but these sectors form a much smaller proportion of total output and investment in these cities than in Xiamen.

Basic data on real net output, labour and real capital stock inputs, single factor productivity and capital labour ratios in Beijing state-owned industry between 1982 and 1988 are outlined in Table 1.3 in Appendix 1. While the total value of real output (in 1980 prices) in the seven sectors examined increased almost 42 per cent over this period, the size of the workforce also rose almost 19 per cent and the deflated value of the capital stock increased a hefty 67 per cent. Beijing's industrial capital stock was also revalued using the methodology described in the previous sections, and the new capital stock deflators constructed by the Institute of Quantitative Economics, CASS.

Table 1.3 indicates that while labour productivity fluctuated, it had risen almost 20 per cent by the end of the period. On the other hand, capital productivity fell by 22 per cent as the capital intensity of production increased. The capital intensity of Beijing industry rose 45 per cent between 1982 and 1988.

Tornqvist indexes of total factor productivity growth were estimated for each of the seven major sectors, using Equation (6). The weights used in the calculation of total factor productivity growth were the constrained factor output elasticities, estimated for each industry from a Cobb-Douglas production function. As in the case of the Xiamen data, this functional form was found to best describe the Beijing production data. Tables 12 and 13 outline the total factor productivity growth and index data for Beijing industry. Total industry total factor productivity indexes were calculated as the weighted average of the industry indexes.

Table 12 Total factor productivity growth of Beijing industry by industry, 1984-1988

	Chemicals	Construction	Forest products	Food products	Machinery	Paper products	Textiles
1984	-0.075	-0.023	0.001	0.159	0.152	-0.035	-0.184
1985	0.026	-0.130	-0.698	-0.195	0.081	-0.227	0.111
1986	0.026	-0.043	0.157	0.035	-0.224	0.087	-0.157
1987	-0.022	-0.001	0.017	-0.079	0.010	-0.190	-0.101
1988	-0.052	-0.074	0.112	0.126	0.104	0.053	0.013

Table 13 Total factor productivity growth indexes of Beijing industry, 1983-1988

	Total	Chemicals	Construction	Forest products	Food products	Machinery	Paper products	Textiles
1983	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1984	0.989	0.925	0.977	1.021	1.159	1.152	0.965	0.816
1985	0.671	0.951	0.847	0.323	0.965	1.233	0.738	0.927
1986	0.750	0.978	0.804	0.480	1.000	1.009	0.825	0.770
1987	0.708	0.956	0.803	0.496	0.921	1.019	0.635	0.699
1988	0.741	0.903	0.730	0.609	1.047	1.123	0.688	0.682

Table 13 indicates that the weighted total factor productivity index of Beijing's state-owned industry sector declined over the period 1983 to 1988, falling in total by 26 per cent, or over 4 per cent per annum. This performance compares poorly with that of industry in Xiamen, which had a 39 per cent increase in productivity between 1983 and 1988. Even state-owned industry in Xiamen achieved a 16 per cent improvement in its productivity over this period. The large machinery and metal products industry and the food products industry were the only two industries to exhibit

any total factor productivity growth, 12 and 5 per cent respectively over the six-year period. All other sectors experienced a fall in total factor productivity, ranging from 10 to 39 per cent.

XI. Shanghai's Industrial Sector Performance

The growth of real net output, real capital stock and labour inputs as well as the capital intensity of production in Shanghai's state-owned industry over the period 1984 to 1988, is outlined in Table 1.4 in Appendix 1. These data indicate that while the value of total real output grew by only 4.25 per cent over the four years to 1988, employment also grew, by 5 per cent and the real value of the capital stock increased by a substantial 47 per cent. Hence labour productivity declined by 6.5 per cent and capital productivity dropped by 29 per cent. The capital intensity of production on the other hand increased by 40 per cent, over the four years to 1988.

Tornqvist indexes of total factor productivity growth were constructed for Shanghai's state-owned industries over the period 1985-1988, as disaggregated data on inputs and outputs by industry have only been available since 1985. The same seven sectors examined in Beijing were analysed, and the same methodology was employed to construct these indexes. Marginal productivities for labour and capital were estimated directly using constrained Cobb-Douglas production functions for each sector.

The estimated total factor productivity growth and indexes of total factor productivity are given in Tables 14 and 15. Table 15 indicates that only three of the seven sectors examined managed to improve their total factor productivity over the four-year period (food processing, furniture, forest products and machinery). The weighted total factor productivity of the total industrial sector declined slightly to 0.99 after four years. That is, total factor productivity in Shanghai's state-owned industry was virtually stagnant over this period.

Table 14 Total factor productivity growth of Shanghai industry by industry, 1986-1988

	Chemicals	Construction	Forest products	Food products	Machinery	Paper products	Textiles
1986	-0.042	-0.035	0.023	-0.072	-0.071	-0.091	-0.082
1987	-0.037	-0.022	-0.100	-0.087	-0.023	-0.016	0.021
1988	0.041	-0.001	0.094	0.171	0.073	0.076	0.036

Table 15 Total factor productivity growth indexes of Shanghai industry, 1985-1988

	Total	Chemicals	Construction	Forest products	Food products	Machinery	Paper products	Textiles
1985	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1986	0.973	0.958	0.965	1.023	0.928	0.929	0.909	0.918
1987	0.914	0.922	0.943	0.924	0.841	0.906	0.894	0.938
1988	0.992	0.962	0.941	1.018	1.012	0.980	0.969	0.974

The productivity performance of Shanghai's state industries appears to have been rather similar to that of Xiamen's total industrial sector (state, collective and joint venture), over the difficult period 1985 to 1988, which included two poor productivity years, 1986 and 1987. Its performance was superior to Xiamen's state sector and rather similar to Beijing's performance over this same period. However, its performance was inferior to that of the non-state sector in Xiamen. However, the shortness of the data set makes it difficult to draw definitive conclusions at this point.

XII. Chinese Industrial Productivity Growth

Finally, the productivity performance of the three industrial cities was compared with that of Chinese state-owned manufacturing industry, over the reform period, 1980 to 1989. Tornqvist indexes of total factor productivity growth were calculated using the same methodology as employed for the regional case studies.[7] Tables 16 and 17, respectively, give estimates indexes and indexes of total factor productivity growth in China's state industry, by the same seven major manufacturing industries.

Table 17 indicates that the performance of different sectors varied widely. As in the three city studies, productivity again appears to have risen significantly in the machinery and metal products industry. It has been stagnant in chemicals and food products but has declined in the construction products, forest products and furniture, textiles and paper products sectors. Closer examination of the input and output data in these industries reveals that this poor performance was due almost entirely to rapid increases in capital investment which were not matched by equivalent rises in output.

Table 16 Total industrial factor productivity growth of Chinese industry, 1982-1989

	Chemicals	Construction	Forest products	Food products	Machinery	Paper products	Textiles
1982	-0.072	-0.057	-0.071	0.013	-0.091	-0.115	0.004
1983	0.062	0.066	-0.002	0.007	0.022	0.004	-0.147
1984	0.090	0.039	0.052	0.014	0.153	0.032	0.008
1985	0.081	-0.073	0.030	0.005	-0.048	0.098	0.151
1986	-0.243	0.018	-0.238	-0.095	0.313	-0.328	-0.312
1987	0.031	0.001	-0.037	0.009	-0.192	0.026	-0.058
1988	0.073	-0.055	0.008	0.043	0.021	0.016	0.058
1989	-0.043	-0.204	-0.057	-0.031	0.121	-0.068	-0.035

Table 17 Index of total industrial total factor productivity growth of Chinese industry, 1981-1989

	Total	Chemicals	Construction	Forest products	Food products	Machinery	Paper products	Textiles
1981	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1982	0.922	0.928	0.943	0.929	1.013	0.909	0.885	1.004
1983	0.935	0.989	1.009	0.927	1.021	0.931	0.888	0.858
1984	1.000	1.079	1.048	0.978	1.034	1.085	0.920	0.865
1985	1.037	1.160	0.975	1.008	1.039	1.036	1.018	1.017
1986	0.866	0.917	0.993	0.770	0.944	1.349	0.690	0.705
1987	0.839	0.948	0.994	0.734	0.953	1.157	0.716	0.647
1988	0.858	1.021	0.938	0.742	0.996	1.179	0.732	0.705
1989	0.814	0.978	0.735	0.684	0.965	1.300	0.664	0.671

Total factor productivity growth for overall industry was calculated as the weighted average of the total factor productivity growth for each sector. This weighted average estimate indicates that there has been a 19 per cent decline in Chinese manufacturing's total factor productivity over the nine years from 1981 to 1989. This performance has been somewhat better than that of Beijing's state-owned sector (for the period 1983 to 1989), but inferior to that of Shanghai's state-owned sector, operating in the coastal city environment, and enjoying numerous other advantages due to the concentration of industry, economies of scale, availability of a skilled workforce and access to foreign technology. On the other hand, the performance of the state-owned, collective and joint-foreign owned sectors in Xiamen has far exceeded the overall performance of state-owned industry in aggregate throughout China.

XIII. Conclusions

The study finds that there has been a strong rise in the rate of total factor productivity growth in Xiamen during the reform period since 1980. While the relative growth of joint-venture and collective firms has contributed significantly to this overall performance over the decade, the state sector has also performed much more strongly than in other industrial cities, like Shanghai and Beijing, and Chinese industry overall.

The analysis of Shanghai's industrial sector's productivity growth was for a shorter period, due to data constraints. State-owned industry there did considerably better than did the state-owned sectors in Beijing or China overall over this period, even though total factor productivity was stagnant. Hence the only firms analysed which actually increased their total factor productivity, were the state-, joint- and collective-owned firms in Xiamen. Within Xiamen, the non-state sector performed significantly better than did the state sector. Hence, the evidence appears to support the hypothesis that the industrial sector reforms of the 1980s assisted in improving productivity performance in the special economic zone of Xiamen, where these policies were implemented more vigorously and possibly prevented a decline in productivity in the open city of Shanghai. However, overall, in the Chinese manufacturing sector, while productivity generally improved in the first half of the 1980s, this was not the case in the latter half of this decade.

The possible reasons for this slowing of productivity growth during the latter half of the reform period include the stop-go macroeconomic policies pursued and the slowing progress of reform in many areas, which were discussed in the previous section. The macroeconomic policies pursued have had a particularly serious impact on productivity in the state sector, where there is little flexibility to vary labour and capital inputs. However, recent announcements from Beijing and the provinces indicate that there is support for accelerated reform in the industrial sector. Hence, the 1990s may well show a pick up in productivity performance.

Notes

1. In early 1990, restrictions were placed on the access of Chinese firms in the special economic zones to foreign exchange (Wall 1990).
2. Estimation undertaken by Zheng Yuxin, Institute of Quantitative Economics, CASS, Beijing.
3. These data have not been used in the productivity estimates for firms of different ownership, as the method of their computation by the SEZ Yearbook does not appear to be compatible with the Xiamen Almanacs (used for 1980-1988), for the data disaggregated by ownership.
4. The estimates of the factor elasticity of output of the whole of Xiamen industry were made using a larger sample of pooled cross section and time series data, disaggregated by ownership and industry sector (250 observations). This approach produced unconstrained regression coefficients for the output elasticity of labour (0.408) and the output elasticity of capital (0.612). Unconstrained estimates were virtually identical to the constrained estimates (0.39995 and 0.60005, respectively).
5. It is not possible to employ absolute measures of total factor productivity because labour and capital inputs are measured in different units; numbers of workers and value of capital stock, rather than comparable units, such as the cost of capital and labour.
6. The share of labour is derived from the wage bill paid by the sector each year, divided by net value added; the share of capital is just estimated as one minus the wage share. In the state sector this may be a substantial underestimate, as it does not include the cost of enterprise-provided housing and other services. As discussed above, the rationale for using factor shares as proxies for factor output elasticities is the assumption that factor and goods markets are competitive, and factors are employed up to the point where their marginal revenue product equals the rent received by the factor.

7. Hence, the extent of divergence of the factor shares and the output elasticity of factors, that is, estimated allocative inefficiency, explains the difference in the estimates of total factor productivities in Tables 7 and 3.1 and Tables 9 and 3.2.
8. Discussions with Professor T. Rawski, June 1992.
9. Estimates were made of the output elasticity of factors from constrained Cobb-Douglas production functions for each major industrial sector. These estimates of the output elasticities of capital and labour were then used as weights in calculating the Tornqvist indexes of total factor productivity growth, and total factor productivity indexes.

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Appendix 1

Table 1.1 Output, employment and capital stock of Xiamen industry by ownership, 1980-1989

	Output	Employment	Capital stock	Q/L	Q/K	K/L
	(¥10,000)	(No. of workers)	(¥10,000)	(¥10,000/ worker)	(¥ output/ ¥ capital)	(¥10,000/ worker)
Total industry						
1980	29178	83542	35569	0.349	0.820	0.426
1981	31189	85438	35377	0.365	0.882	0.414
1982	34467	87270	38246	0.395	0.901	0.438
1983	36983	91095	40753	0.406	0.907	0.447
1984	45260	93728	42481	0.483	1.065	0.453
1985	65777	101492	55485	0.648	1.185	0.547
1986	75136	107372	75997	0.700	0.989	0.708
1987	89094	116075	109443	0.768	0.814	0.943
1988	118671	130431	127233	0.910	0.933	0.975
1989	172074	224834	172326	0.765	0.999	0.951
State industry						
1980	23408	54325	30041	0.430	0.779	0.552
1981	24757	55095	29488	0.449	0.839	0.535
1982	28053	56463	31404	0.496	0.893	0.556
1983	29866	60507	33198	0.493	0.899	0.548
1984	36744	61463	33720	0.597	1.089	0.548
1985	44144	64801	39143	0.681	1.127	0.604
1986	46718	65007	51796	0.718	0.901	0.796
1987	53911	65499	69068	0.823	0.780	1.054
1988	65729	72780	70139	0.903	0.937	0.963
1989	77960	124473	110096	0.626	0.708	0.884

Table 1.1 (Continued)

Collective industry						
1980	5770	29217	5528	0.197	1.043777	0.189205
1981	6431	30343	5889	0.211	1.092155	0.194081
1982	6413	30807	6842	0.208	0.937401	0.222092
1983	7115	30588	7555	0.232	0.941880	0.246992
1984	7853	29944	8323	0.262	0.943626	0.277952
1985	9839	31017	9560	0.317	1.029236	0.308218
1986	10324	32654	9801	0.316	1.053382	0.300147
1987	10830	34347	10751	0.315	1.007432	0.313011
1988	13350	33349	12904	0.400	1.034563	0.386938
1989	14931	67142	12644	0.222	1.180952	0.188317
Joint industry						
1984	662.10	2321	438	0.285	1.511644	0.188712
1985	11793.10	5674	6782	2.078	1.738882	1.195277
1986	18092.50	9711	14400	1.863	1.256424	1.482854
1987	24352.50	16229	29624	1.500	0.822053	1.825374
1988	39591.20	24302	44190	1.629	0.895931	1.818369
1989	79432.00	33219	49586	2.391	1.601904	1.492700

Table 1.2 Output, employment and capital stock of Xiamen industry by industry, 1980-1989

	Output	Employment	Capital stock	Q/K	Q/L	K/L
	(¥10,000)	(No. of workers)	(¥10,000)	(¥/¥ capital)	(¥10,000/ worker)	(¥10,000/ worker)
Chemicals						
1980	5848.85	11326	5328	0.516	1.097	0.470
1981	6671.54	12114	7233	0.550	0.922	0.597
1982	7770.85	12595	7244	0.616	1.072	0.575
1983	8365.12	12992	7457	0.643	1.121	0.573
1984	8553.22	13794	7520	0.620	1.137	0.545
1985	9663.16	18472	7962	0.523	1.213	0.431
1986	10725.05	19441	8706	0.551	1.231	0.447
1987	16647.00	19844	25899	0.838	0.642	1.305
1988	26661.00	23844	40624	1.118	0.656	1.703
1989	27204.51	24249	45853	1.121	0.593	1.890
Construction products						
1980	1557.55	5306	3788	0.293	0.411	0.713
1981	2116.24	5968	3934	0.354	0.537	0.659
1982	2140.14	6151	3983	0.347	0.537	0.647
1983	3803.19	6447	4029	0.589	0.943	0.624
1984	5100.96	7045	4047	0.724	1.260	0.574
1985	4829.40	9459	4182	0.510	1.154	0.442
1986	4931.89	9065	4552	0.544	1.083	0.502
1987	3478.00	7821	4942	0.444	0.703	0.631
1988	4483.00	9692	5085	0.462	0.881	0.524
1989	3013.00	9354	5105	0.322	0.590	0.545
Forest products and furniture						
1980		1665	510	0.475	1.551	0.306
1981	824.85	1611	511	0.512	1.614	0.317

Table 1.2 (Continued)

1982	1258.91	1570	517	0.801	2.435	0.329
1983	1503.02	1500	559	1.002	2.688	0.372
1984	1241.74	1625	591	0.764	2.101	0.363
1985	1014.54	2300	616	0.441	1.646	0.267
1986	797.23	2123	675	0.375	1.181	0.317
1987	757.00	1928	702	0.392	1.078	0.364
1988	1069.00	2026	1067	0.527	1.001	0.526
1989	722.95	1891	1247	0.382	0.579	0.659
Footwear						
1980	9496.37	12268	7485	0.774	1.268	0.610
1981	10140.79	12507	7582	0.810	1.337	0.606
1982	11801.74	13635	7599	0.865	1.553	0.557
1983	12641.82	15648	8024	0.807	1.575	0.512
1984	17795.14	15829	8882	1.124	2.003	0.561
1985	21944.45	18068	10250	1.214	2.140	0.567
1986	26026.25	18454	12669	1.410	2.054	0.686
1987	27499.00	19300	16145	1.424	1.703	0.836
1988	37148.00	20094	19692	1.848	1.886	0.979
1989	35374.50	21419	20288	1.651	1.743	0.947
Metallurgy						
1980	107.42	875	710	0.122	0.151	0.811
1981	104.80	724	780	0.144	0.134	1.077
1982	118.11	668	800	0.176	0.147	1.197
1983	145.42	669	836	0.217	0.173	1.249
1984	178.73	646	1458	0.276	0.122	2.256
1985	696.31	904	1418	0.770	0.491	1.568
1986	1092.62	891	1390	1.226	0.786	1.560
1987	889.00	861	1354	1.032	0.656	1.572
1988	2110.00	1538	1314	1.371	1.605	0.854
1989	1601.00	847	1153	1.890	1.388	1.361

Table 1.2 (Continued)

Paper products						
1980	1943.59	4024	927	0.483	2.096	0.230
1981	2377.34	5075	949	0.468	2.505	0.186
1982	2458.54	5879	1067	0.418	2.304	0.181
1983	2536.62	6721	1288	0.377	1.969	0.191
1984	3114.79	7536	1402	0.413	2.221	0.186
1985	4743.36	8618	1523	0.550	3.114	0.176
1986	5830.51	8753	1759	0.666	3.314	0.200
1987	4562.00	9224	2218	0.494	2.056	0.240
1988	5203.00	8854	2399	0.587	2.168	0.270
1989	5968.75	6380	2926	0.935	2.039	0.458
Textiles						
1980	2868.00	8831	3724	0.324	0.770	0.421
1981	3900.10	9556	3747	0.408	1.040	0.392
1982	3148.90	10033	3807	0.313	0.827	0.379
1983	2718.00	10254	4054	0.265	0.670	0.395
1984	3121.70	10376	4080	0.300	0.765	0.393
1985	3950.10	8934	4797	0.442	0.823	0.536
1986	4105.80	9458	6160	0.434	0.666	0.651
1987	4124.40	9792	8624	0.421	0.478	0.880
1988	5610.50	10122	8763	0.554	0.640	0.865
1989	5081.90	11171	11397	0.454	0.445	1.020
Garments						
1980	328.00	1107	99	0.296	3.313	0.089
1981	399.80	1258	172	0.317	2.324	0.136
1982	277.60	1152	247	0.240	1.123	0.214
1983	297.40	1132	350	0.262	0.849	0.309
1984	444.10	1289	500	0.344	0.888	0.387
1985	817.40	2774	804	0.294	1.016	0.289
1986	926.00	3277	1302	0.282	0.711	0.397

Table 1.2 (Continued)

1987	975.90	3878	1872	0.251	0.521	0.482
1988	1424.50	4925	2019	0.289	0.705	0.409
1989	2206.00	5135	2463	0.429	0.895	0.479
Leather products						
1980	559.00	917	382	0.609	1.463	0.416
1981	324.00	973	421	0.332	0.769	0.432
1982	267.70	940	427	0.284	0.626	0.454
1983	354.00	968	508	0.365	0.696	0.524
1984	487.60	870	553	0.560	0.881	0.635
1985	437.00	1741	566	0.251	0.772	0.325
1986	540.50	1921	594	0.281	0.909	0.309
1987	610.00	2197	624	0.277	0.977	0.284
1988	534.60	2456	640	0.217	0.835	0.260
1989	698.50	2280	803	0.306	0.869	0.352

Table 1.3 Output, employment and capital stock of Beijing industry by industry, 1982-1988

	Output	Capital stock	Employment	Q/L	Q/K	K/L
	(¥10,000)	(¥10,000)	(No. of workers)	(¥10,000/ worker)	(¥/¥ capital)	(¥10,000/ worker)
Total						
1982	572799	588999	1048198	0.546	0.972	0.562
1983	600684	634422	1073355	0.560	0.947	0.591
1984	674236	647283	985781	0.684	1.042	0.657
1985	687398	682646	1248099	0.551	1.007	0.547
1986	607300	721823	1254984	0.484	0.841	0.575
1987	629055	812633	1255129	0.501	0.774	0.647
1988	721022	884131	1247257	0.578	0.816	0.709
Chemicals						
1982	194183	174297	110760	1.753	1.114	1.574
1983	199066	179248	112103	1.776	1.111	1.599
1984	217556	177580	162694	1.337	1.225	1.091
1985	195052	190264	133816	1.458	1.025	1.422
1986	169242	173647	93665	1.807	0.975	1.854
1987	178452	198155	100228	1.780	0.901	1.977
1988	193066	206899	102557	1.883	0.933	2.017
Construction materials						
1982	30576	44027	75296	0.406	0.694	0.585
1983	32442	56409	78542	0.413	0.575	0.718
1984	34669	68926	82681	0.419	0.503	0.834
1985	41943	68421	120372	0.348	0.613	0.568
1986	44023	82863	129368	0.340	0.531	0.641
1987	45119	87335	131121	0.344	0.517	0.666
1988	45059	94213	126604	0.356	0.478	0.744

Table 1.3 (Continued)

Machinery and metallurgy						
1982	189686	277273	601771	0.315	0.684	0.461
1983	212967	284971	599345	0.355	0.747	0.475
1984	254292	277558	618752	0.411	0.916	0.449
1985	288771	285118	607065	0.476	1.013	0.470
1986	233087	304586	628147	0.371	0.765	0.485
1987	250139	340949	621280	0.403	0.734	0.549
1988	301546	371454	618854	0.487	0.812	0.600
Furniture and forest products						
1982	13194	10586	27540	0.479	1.246	0.384
1983	13458	11315	28044	0.480	1.189	0.403
1984	14142	10924	28479	0.497	1.295	0.384
1985	9316	11044	34915	0.267	0.844	0.316
1986	11427	16598	38554	0.296	0.688	0.431
1987	12774	18255	38863	0.329	0.700	0.470
1988	13170	17998	37411	0.352	0.732	0.481
Food, beverages and tobacco						
1982	36969	25695	58818	0.629	1.439	0.437
1983	43846	29724	63780	0.687	1.475	0.466
1984	48595	34982	64177	0.757	1.389	0.545
1985	49609	44154	83240	0.596	1.124	0.530
1986	51394	56593	88748	0.579	0.908	0.638
1987	48204	64991	92978	0.518	0.742	0.699
1988	58208	80682	96928	0.601	0.721	0.832
Textiles						
1982	102444	51894	164015	0.625	1.974	0.316
1983	92884	67364	181179	0.513	1.379	0.372
1984	98842	71550	18354	5.385	1.381	3.898
1985	96467	77854	246793	0.391	1.239	0.315

Table 1.3 (Continued)

1986	89101	77738	253681	0.351	1.146	0.306
1987	84978	91410	247538	0.343	0.930	0.369
1988	97933	96673	242835	0.403	1.013	0.398
Paper products						
1982	5748	5227	9997	0.575	1.100	0.523
1983	6022	5391	10361	0.581	1.117	0.520
1984	6141	5765	10645	0.577	1.065	0.542
1985	6239	5792	21898	0.285	1.077	0.264
1986	9027	9797	23588	0.383	0.921	0.415
1987	9388	11539	23121	0.406	0.814	0.499
1988	12040	16213	22068	0.546	0.743	0.735

Table 1.4 Output, employment and capital stock of Shanghai industry by industry, 1985-1988

	Output (¥100,000)	Employment (No. of workers)	Capital stock (¥ Mn)	Q/L (¥'000/ worker)	Q/K (¥/¥ capital)	K/L (¥'000/ worker)
Total						
1985	168936	2525800	90828	6.688	0.186	35.960
1986	159415	2586000	101164	6.165	0.158	39.120
1987	154248	2622600	109722	5.881	0.141	41.837
1988	166584	2652700	110610	6.280	0.151	41.697
Chemicals						
1985	20429	170600	9140	11.975	0.224	53.577
1986	19665	176900	9325	11.116	0.211	52.712
1987	18934	175100	8963	10.813	0.211	51.187
1988	20456	177200	9773	11.544	0.209	55.153
Construction products						
1985	6650	150300	4570	4.425	0.146	30.407
1986	6498	152800	4841	4.252	0.134	31.679
1987	6380	158400	5986	4.028	0.107	37.791
1988	6443	155500	7603	4.143	0.085	48.894
Forest products and furniture						
1985	1889	41900	1028	4.509	0.184	24.526
1986	1817	41200	1111	4.411	0.164	26.958
1987	1591	37900	1163	4.199	0.137	30.696
1988	1550	36700	1196	4.224	0.130	32.583
Food processing						
1985	11370	106300	3466	10.696	0.328	32.605
1986	11279	110900	4205	10.171	0.268	37.917
1987	11314	117200	5112	9.654	0.221	43.620
1988	14544	117900	5541	12.336	0.262	46.998

Table 1.4 (Continued)

Machinery and metallurgy						
1985	78564	1233900	40920	6.367	0.192	33.163
1986	72832	1261000	42383	5.776	0.172	33.611
1987	70482	1270500	45284	5.548	0.156	35.642
1988	74577	1276400	45318	5.843	0.165	35.504
Paper products						
1985	3086	43200	1232	7.143	0.250	28.516
1986	2769	43800	1532	6.322	0.181	34.985
1987	3058	47300	1775	6.466	0.172	37.528
1988	3242	47900	2308	6.768	0.140	48.183
Textiles and clothing						
1985	46947	779600	30472	6.022	0.154	39.086
1986	44555	799400	37768	5.574	0.118	47.245
1987	42489	816200	41439	5.206	0.103	50.770
1988	45772	841100	38871	5.442	0.118	46.215

Table 1.5 Output, employment and capital stock of Chinese industry by industry, 1980-1988

	Output (¥100,000)	Employment (No. of workers)	Capital stock (¥ Mn)	Q/L (¥'000/ worker)	Q/K (¥/¥ capital)	K/L (¥'000/ worker)
Total						
1980	1103.06	2306.80	1409.24	0.478	0.783	0.611
1981	1131.95	2435.40	1533.85	0.465	0.738	0.630
1982	1191.52	2507.60	1688.26	0.475	0.706	0.673
1983	1318.80	2537.30	1769.66	0.520	0.745	0.697
1984	1528.49	2550.20	2263.76	0.599	0.675	0.888
1985	1804.37	3620.00	2361.74	0.498	0.764	0.652
1986	1892.55	3759.40	2781.90	0.503	0.680	0.740
1987	2104.66	3894.50	3100.86	0.540	0.679	0.796
1988	2381.85	4441.20	3543.30	0.536	0.672	0.798
Chemical industry						
1980	173.24	300.00	262.91	0.577	0.659	0.876
1981	175.25	307.10	290.27	0.571	0.604	0.945
1982	194.78	312.90	305.19	0.622	0.638	0.975
1983	217.35	318.10	311.66	0.683	0.697	0.980
1984	242.83	326.70	321.31	0.743	0.756	0.984
1985	229.35	370.70	392.78	0.619	0.584	1.060
1986	246.31	387.60	408.66	0.635	0.603	1.054
1987	290.47	415.00	450.58	0.700	0.645	1.086
1988	321.68	461.10	526.38	0.698	0.611	1.142
Construction industry						
1980	78.82	191.00	112.69	0.413	0.699	0.590
1981	76.75	192.10	120.83	0.400	0.635	0.629
1982	85.18	195.80	129.63	0.435	0.657	0.662
1983	91.91	199.70	138.48	0.460	0.664	0.693
1984	105.16	205.50	228.27	0.512	0.461	1.111

Table 1.5 (Continued)

1985	147.95	314.40	267.24	0.471	0.554	0.850
1986	165.65	331.70	328.55	0.499	0.504	0.991
1987	166.21	337.70	372.50	0.492	0.446	1.103
1988	154.38	395.50	405.29	0.390	0.381	1.025
Machinery and metal products industry						
1980	367.07	980.50	659.81	0.374	0.556	0.673
1981	342.79	1015.10	675.51	0.338	0.507	0.665
1982	376.84	1030.90	723.19	0.366	0.521	0.702
1983	447.82	1033.50	736.22	0.433	0.608	0.712
1984	542.44	1038.20	919.90	0.522	0.590	0.886
1985	695.19	1447.60	887.95	0.480	0.783	0.613
1986	711.34	1466.80	1084.58	0.485	0.656	0.739
1987	790.87	1494.80	1174.50	0.529	0.673	0.786
1988	946.27	1679.40	1249.94	0.563	0.757	0.744
Forest products and furniture industry						
1980	37.78	126.20	68.82	0.299	0.549	0.545
1981	36.92	131.80	74.31	0.280	0.497	0.564
1982	37.71	134.00	79.58	0.281	0.474	0.594
1983	39.54	133.00	80.88	0.297	0.489	0.608
1984	41.81	132.80	98.70	0.315	0.424	0.743
1985	44.29	184.70	106.54	0.240	0.416	0.577
1986	44.61	191.50	117.15	0.233	0.381	0.612
1987	45.64	192.30	126.94	0.237	0.360	0.660
1988	51.45	233.80	135.01	0.220	0.381	0.577
Food processing industry						
1980	141.26	234.00	117.68	0.604	1.200	0.503
1981	160.95	256.10	140.44	0.628	1.146	0.548
1982	177.39	274.40	161.06	0.646	1.101	0.587
1983	189.42	280.60	181.31	0.675	1.045	0.646
1984	212.46	288.00	243.65	0.738	0.872	0.846
1985	231.60	349.90	283.72	0.662	0.816	0.811

Table 1.5 (Continued)

1986	258.13	374.60	335.91	0.689	0.768	0.897
1987	291.11	392.20	388.58	0.742	0.749	0.991
1988	328.21	443.90	480.04	0.739	0.684	1.081
Textiles and garments industry						
1980	247.94	371.40	154.47	0.668	1.605	0.416
1981	285.19	425.10	178.38	0.671	1.599	0.420
1982	263.74	448.70	230.97	0.588	1.142	0.515
1983	274.30	460.40	258.14	0.596	1.063	0.561
1984	318.40	445.80	383.55	0.714	0.830	0.860
1985	366.88	735.90	321.17	0.499	1.142	0.436
1986	368.64	776.90	381.59	0.474	0.966	0.491
1987	415.33	820.50	440.74	0.506	0.942	0.537
1988	461.11	933.60	579.96	0.494	0.795	0.621
Paper and publishing industry						
1980	56.95	103.70	32.86	0.549	1.733	0.317
1981	54.11	108.10	54.10	0.501	1.000	0.500
1982	55.88	110.90	58.64	0.504	0.953	0.529
1983	58.46	112.00	62.97	0.522	0.928	0.562
1984	65.39	113.20	68.38	0.578	0.956	0.604
1985	89.11	216.80	102.34	0.411	0.871	0.472
1986	97.86	230.30	125.46	0.425	0.780	0.545
1987	105.02	242.00	147.01	0.434	0.714	0.607
1988	118.75	293.90	166.68	0.404	0.712	0.567

Appendix 2 Tests of specification of and constraints on the functional form

Table 2.1 F-ratio tests of constrained and unconstrained Cobb-Douglas and translog production functions

	F-ratio	F-stat	F-ratio	F-stat
	Const RTS CD[(1)]		Translog vs CD[(2)]	
Total industry	.0047	4.17	.033	2.69
State industry	.004	4.35	.002	2.50
Collective industry	.0013	4.35	.0014	2.50
Joint industry	.00	4.35	.0006	2.50
Chemical industry	.00	3.97	.003	2.87
Construction products industry	.0025	3.97	.012	2.87
Forest products and furniture industry	.00	3.97	.011	2.87
Footwear industry	.005	3.97	.002	2.87
Metallurgy industry	.002	3.97	.013	2.87
Other manufacturing industry	.004	3.97	.003	2.87
Paper industry	.020	3.97	.008	2.87
Textiles industry	.098	3.97	.037	2.87

Notes: (1) F-ratio compares the CRS Cobb-Douglas production function with the unconstrained CD production function.

(2) F-ratio compares the CRS Cobb-Douglas production function with an unconstrained translog production function.

Appendix 3

Table 3.1 TFP growth, factor share weights by ownership, 1979-1988

	Total	State	Collective	Joint
1979	-0.012	-0.016	0.012	0.000
1980	-0.013	-0.016	-0.002	0.000
1981	0.031	0.016	0.066	0.000
1982	0.036	0.047	-0.024	0.000
1983	-0.044	-0.055	-0.030	0.000
1984	0.140	0.157	0.076	0.284
1985	0.157	0.227	-0.206	0.176
1986	-0.108	-0.074	-0.056	-0.399
1987	-0.299	-0.411	-0.099	-0.091
1988	0.119	0.153	0.023	0.028
Total	0.007	0.028	-0.241	-0.001
Average TFP growth	0.001	0.003	-0.024	0.000

Table 3.2 TFP growth, factor share weights by industry, 1980-1988

	Total	Chemicals	Construction	Forest products	Footwear	Metallurgy	Manufactory	Paper products	Textiles and clothing
1980	-0.013	0.078	-0.116	0.003	-0.198	-0.046	-0.006	0.024	0.080
1981	0.031	-0.015	0.184	0.033	0.051	0.098	0.017	0.081	0.028
1982	0.036	0.088	-0.077	0.391	0.036	0.157	0.150	-0.069	-0.293
1983	-0.044	-0.104	0.427	0.130	-0.085	0.145	-0.092	-0.163	-0.251
1984	0.140	-0.152	0.244	-0.136	0.274	0.603	0.217	0.103	0.041
1985	0.157	-0.236	-0.461	-0.612	-0.067	0.856	0.393	0.134	0.317
1986	-0.108	-0.536	-0.070	-0.394	0.009	0.138	0.042	-0.213	-0.114
1987	-0.299	0.165	-0.431	-0.061	-0.177	-0.641	-0.488	-0.475	-0.430
1988	0.119	0.285	0.097	0.122	-0.156	0.423	0.119	-0.117	0.040
Total	0.019	-0.428	-0.204	-0.524	-0.313	1.732	0.353	-0.695	-0.582
Average TFP growth	0.002	-0.048	-0.023	-0.058	-0.035	0.192	0.039	-0.077	-0.065

Appendix 4

Table 4.1 Chinese capital stock deflators, 1980-1989

	Metallurgy	Chemicals	Machinery	Construction	Forest products	Food products
1980	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1981	1.1107	1.0979	1.1011	1.1209	1.0893	1.1014
1982	1.1106	1.1436	1.1231	1.1352	1.1255	1.1151
1983	1.2369	1.2493	1.2425	1.2986	1.2530	1.2281
1984	1.3479	1.3475	1.3105	1.4044	1.3683	1.3589
1985	1.4709	1.4372	1.4122	1.5304	1.4771	1.4480
1986	1.5817	1.5390	1.5010	1.5926	1.6608	1.5451
1987	1.7119	1.6282	1.5574	1.6767	1.6756	1.6227
1988	1.8410	1.7547	1.6785	1.8988	1.8259	1.7596
1989	2.0571	1.9093	1.8056	2.0639	2.1918	1.9512
	Textiles	Garments	Leather products	Paper and printing	Arts and education	Others
1980	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1981	1.1025	1.0970	1.0956	1.0959	1.0964	1.0952
1982	1.1228	1.1188	1.1085	1.0911	1.0940	1.1056
1983	1.2306	1.2269	1.2209	1.2255	1.2332	1.2226
1984	1.3149	1.4609	1.3790	1.3010	1.3034	1.3798
1985	1.4173	1.4043	1.3194	1.3978	1.3965	1.4806
1986	1.4487	1.6215	1.5664	1.4821	1.4766	1.6314
1987	1.5325	1.5603	1.5861	1.5714	1.4642	1.8375
1988	1.6668	1.6860	1.7122	1.6895	1.5624	2.0096
1989	1.9265	2.1934	1.9525	1.9664	1.8190	2.3319

Table 4.2 Chinese output deflators, 1980-1989

	Metallurgy	Chemicals	Machinery	Construction	Forest products
1980	1.0000	1.0000	1.0000	1.0000	1.0000
1981	1.0179	0.9727	0.9865	1.0119	1.1463
1982	1.0289	0.9705	0.9798	1.0378	1.2390
1983	1.0404	0.9841	0.9741	1.0792	1.2340
1984	1.0826	1.0156	0.9918	1.1155	1.2913
1985	1.2164	1.0056	1.0587	1.2239	1.4554
1986	1.3302	1.0374	1.0701	1.3081	1.5663
1987	1.4256	1.1303	1.0868	1.3967	1.9667
1988	1.6023	1.3137	1.1354	1.6626	2.1118
1989	1.9220	1.5366	1.2602	1.9773	2.2061
	Food products	Textiles	Garments	Leather products	Paper and printing
1980	1.0000	1.0000	1.0000	1.0000	1.0000
1981	1.0229	0.9907	0.9613	1.0157	1.0866
1982	1.0576	0.9558	0.9611	1.0025	1.1036
1983	1.0670	0.8999	0.8886	1.0342	1.1194
1984	1.0880	0.8499	0.8632	1.0517	1.1154
1985	1.1548	0.8820	0.9317	1.2542	1.2247
1986	1.2046	0.9866	0.9354	1.2971	1.2750
1987	1.2916	0.9914	0.9828	1.3777	1.4452
1988	1.5007	1.1022	1.1028	1.5770	1.5760
1989	1.7071	1.8040	1.1836	1.7765	1.7944

6

The Impact of Partially-introduced Market Mechanisms on Industrial Efficiency

The Case of Chinese Iron and Steel Industry

Cao Yong

I. Introduction

This study focuses on the evaluation of the impacts of market-oriented economic reforms on industrial efficiency in the Chinese iron and steel industry during the reform period of the 1980s. Impetus was given to market-oriented economic reforms by the pervasive inefficiency in the utilization of factor inputs and hence the poor productivity performance of the Chinese industrial sector under central planning. Economic resources were not allocated according to their marginal productivities. Inefficient allocation of resources was related to the lack of incentive for enterprises and individual workers to use factors of production effectively; distorted factor and goods markets meant that signals for resource allocation were inappropriate, and there was a lack of mobility of economic resources across industrial sectors, enterprises and regions.

Reforms were expected to improve industrial productivity by introducing some elements of the market mechanism into the centrally planned economic system. The effects of the partial introduction of elements of a market system to overcome inefficient resource allocation and hence to improve productivity has, however, not been empirically tested. This study undertakes such empirical tests.

Reforms had the potential to influence productivity in three ways:

- through the creation of greater incentives for enterprises and individual workers to utilize factors of production more effectively and hence improve productivity;
- through the creation of factor and goods markets which would enable economic resources to be more efficiently allocated according to their marginal productivities;
- through an improvement in the mobility of economic resources across regions, industrial sectors and enterprises.

The aim of this study is then to develop measures of industrial performance to assess the impact of reforms on the three aspects. The methodology applied is to disaggregate industrial productivity performance into technical, allocative and scale efficiencies. These distinctive efficiency measures are expected to provide detailed and unbiased estimates of the effect of the development of a market mechanism on industrial productivity.

The structure of this chapter is as follows: the decomposition of productive efficiency is briefly discussed in Section II to provide a theoretical framework for the rest of the analysis. Some stylized facts of market imperfections in the Chinese economy are indicated and their expected impacts on productive efficiency are assessed in Section III. Section IV presents the methodology of econometric estimation. Data used in the estimation are discussed in Section V. Section VI reports the empirical results. Findings in this study are finally summarized in Section VII.

II. The Decomposition of Productive Efficiency into Technical, Allocative and Scale Efficiencies

Farrell (1957) is considered the pioneer in the use of the production frontier to decompose productive efficiency into two subcategories: technical efficiency and allocative efficiency. Forsund et al. (1980) decomposed productive efficiency into three components by adding scale efficiency to technical and allocative efficiencies.

Assuming the following standard formulations of production, cost and profit functions respectively:

$$Y = f(X)$$
$$C(Y, X) = \mathrm{Min}_X \{WX \mid f(X) \geq Y, X \geq 0\}$$
$$\Pi(P, W) = \mathrm{Max}_{Y,X} \{PY - WX \mid f(X) \geq Y, Y \geq 0, X \geq 0\} \quad (1)$$

where, Y is the vector of outputs, X is the vector of inputs, W is the vector of input prices, P is the vector of output prices and C and Π are the cost and profit functions respectively. If a production unit is observed at (Y^0, X^0), then for:

Technical efficiency: $Y^0 = f(X^0)$
Technical inefficiency: $Y^0 < f(X^0)$.

Technical inefficiency is due to excessive input usage for a given output, and if this is the case costs are then:

$$WX^0 > C(Y^0, W).$$

Since cost is not minimized, profit is not maximized:

$$(PY^0 - WX^0) < \Pi(P, W).$$

If cost is minimized, we can accordingly define:

Allocative efficiency: $f_i(X^0) / f_j(X^0) = W_i / W_j$
Allocative inefficiency: $f_i(X^0) / f_j(X^0) \neq W_i / W_j$

where $f_i(X^0)$ and $f_j(X^0)$ are the marginal products of inputs i and j, and W_i and W_j are the prices of factors i and j respectively. Allocative inefficiency results from employing inputs in the wrong proportions relative to their prices, which is costly and hence:

$WX^0 > C(Y^0, W)$.

As cost is not minimized, profit is not maximized:

$(PY^0 - WX^0) < \Pi(P, W)$.

Obviously, if and only if $WX^0 = C(Y^0, W)$ and $(PY^0 - WX^0) = \Pi(P, W)$, can the production unit ensure its overall efficiency. As neither the arguments of technical nor allocative efficiency involve the vector of output prices, they are not sufficient to ensure $(PY^0 - WX^0) = \Pi(P, W)$. At this point we have to introduce scale efficiency to achieve overall efficiency:

Scale efficiency: $P = C_Y(Y^0, W)$

Scale inefficiency: $P \neq C_Y(Y^0, W)$

where $C_Y(Y^0, W)$ is the marginal cost of production from increasing the scale of output. A production unit will be scale inefficient if it produces above or below the optimum output level and hence fails to equalize its marginal cost to output price.

Unlike the so-called "residual" estimations of productivity, such as the estimation of total factor productivity, the decomposition of efficiency isolates the different aspects of an enterprise's performance by relating them to their respective causes. Therefore, estimates of decomposed efficiency can reveal more specific economic information on why enterprises' productive efficiency has or has not improved. For example, many enterprises might be found to be technically inefficient. This may be due to insufficient incentives, such as lack of ownership or other profit-related incentives. Alternatively, enterprises may be found to be technically efficient but allocatively inefficient. This suggests that factor markets are distorted and that, to improve enterprises' productive efficiency, relevant economic policies should be adopted to minimize distortions in factor markets. Furthermore, a considerable number of enterprises might be found to be technically and allocatively efficient but not scale efficient. This suggests that the industrial market structure is distorted and that enterprises with potential scale economies cannot fully exploit their potential lower production cost to increase their share of total industrial production. On the other hand, scale-inefficient enterprises may be able to expand even though they have a cost disadvantage. Therefore, industrial and liberalization policies that are neutral regarding the development of enterprises with economies of scale are a means of improving industrial performance.

The theory of decomposed productive efficiency has recently been widely applied to enterprises in market economies (Kalirajan and Shand 1985; Van den Broeck 1988; Kumbhakar et al. 1989). In most of these studies, differences in productive efficiency among enterprises were found from the estimates of the three decomposed efficiencies. Because all these efficiency measures corresponded to enterprises' behaviour in seeking to maximize profit under given market conditions, the resultant differences in enterprise-specific efficiencies were interpreted as an indication of market imperfection. As far as Chinese enterprises are concerned, estimates of decomposed efficiency allow one to judge not only individual enterprises' performance but also the constraints market distortions place on enterprises' performance.

III. The Stylized Facts of the Partially-introduced Market Mechanisms and Their Impacts on Industrial Efficiency

Although there was no comprehensive blueprint for economic reforms in the Chinese industrial sector in the 1980s, fundamental changes were introduced in almost every area of the economy. Asset ownership, industrial planning, financing, pricing, labour allocation and worker income determination and commodity distribution all underwent some change.

The reforms aimed to replace the previously highly centralized planned economy with a system containing elements of both planning and market. The primary purpose of reforms was to provide incentives to local governments and enterprises to utilize their assets more effectively to further their own self-interest and thereby improve national economic efficiency. However, the reforms were contradictory in many aspects.

The principle of self-interest governed the behaviour of workers, enterprises and even local governments while a hierarchical control structure by government bureaucrats remained. Local governments became more important in a newly adjusted hierarchical control structure and tried to protect local industrial development from national competition. This change had the serious effect of causing the industrial markets to develop in a locally segmented manner.

The efforts at separating ownership and control rights between state agencies and state-owned enterprises did little to alter the traditional structure of socialist ownership. As a result, the economic activities of enterprises continued to be subject to direct intervention from government agencies. The mobility of capital and other resources between enterprises and regions was even more restricted than previously, as local governments introduced restrictions to protect their revenue sources.

The central goal of the economic reforms was to increase profit-maximization behaviour (Tidrick and Chen 1987:1-11; Wilson III and Gordon 1990; Kosta 1989; Kornai 1990). The sequencing of this change in firms' behaviour was very critical for the economic reforms. If firms had exhibited profit-maximizing behaviour and actively responded to the market-based reform policies, an efficiency gain in the Chinese economy would have been expected. This would have occurred because firms were considering the costs and benefits associated with their investment and production decisions. If an empirical study is to be used to justify the feasibility or desirability of the market-oriented economic reforms, it is necessary to determine if an efficiency gain was achieved.

It has been, however, widely argued among Chinese economists that firms did not show normal market-based behaviour in their responses to the reform policies but primarily sought rents in the reform process itself (Zhang et al. 1987; Den and Lo 1987; Dai and Li 1988; Du et al. 1990). The partial introduction of a market

mechanism resulted in seriously distorted output and input markets and a seriously distorted redistribution of income, leading to concerns that any further reform would engender enormous economic and social uncertainties. The current debate about the economic reforms in China and about other centrally planned economies is focused on whether they can be reformed at all (Kosta 1989; Petr 1990). Nordhaus (1990) has even proposed a Murphy's law for economic reforms in centrally planned economies: partial reformation of an internally consistent planned economy makes things worse before they get better.

The above concerns seem to confuse the effects of the micro-level reforms on enterprises' behaviour with the effects of market imperfections on industrial performance. The focus of the empirical study of micro reforms is on whether there was any systematic difference in industrial performance during the reform period as enterprises started to seek profit rather than quantity maximization.[1] In relation to market imperfections, the empirical study focuses on how enterprises could achieve profit maximization within the prevailing distorted market system. Market-oriented behaviour by enterprises might have improved industrial performance, but market imperfections may have resulted in a deterioration. If this is the case, the evaluation of the effect of economic reforms on industrial performance may be confused by attempting to measure two distinctive effects simultaneously.[2] It is, therefore, very critical to distinguish enterprises' productive efficiency in distorted factors and goods markets.

Capital

The accounts of Chinese enterprises divide capital into fixed and working capital. Fixed capital consists of capital stocks from centrally allocated investment in the pre-reform period, from investment undertaken following the first introduction of reforms from enterprises' accumulated fund, from investment financed by bank loans and investment from local government and, in some instances, from central government in the reform period. Working capital consists of that portion determined by central plans before the economic reforms and provided by banks to enterprises, bank loans and the enterprises' own accumulation. Among these sources of capital, the only truly endogenous variable for enterprises was their own accumulation of funds. Enterprises had full control over their own accumulation, and more importantly these funds involved an opportunity cost. Enterprises also incurred costs using bank loans. But whether bank loans were efficiently allocated among enterprises or whether enterprises paid the true economic cost of these funds, depended on whether interest rates were at equilibrium levels and whether enterprises were actually required to repay the loans. Enterprises' behaviour regarding capital formation and utilization can be examined in relation to the different sources of capital funds:

- In attempting to minimize production costs or maximize profits, enterprises should have effectively utilized capital stock allocated to them regardless of its source. Accordingly, an improvement of technical efficiency should have resulted. Provided enterprises and workers could retain part of the benefits from utilizing production capacity more efficiently, a more efficient utilization of the capacity should have occurred as a result of the enterprises' and workers' response to economic incentives introduced by the reforms.
- In attempting to minimize production costs or maximize profits, enterprises should have sought to economize on capital purchased from their accumulated funds so that the marginal productivities of these capital inputs equalled their marginal costs. An improvement in enterprises' allocative efficiency in the use of capital investment under their control should have occurred. Enterprises were also able to use the capital investment under their control to correct existing misallocations of resources. For example, enterprises could implement investment from their own funds to improve the compatibility of different types of production equipment. Enterprises' effort in this regard would contribute to improved technical efficiency.

- The change from granting enterprises funds freely from banks during the pre-reform period to charging enterprises interest rates during the reform period would have put some constraints on enterprises in obtaining funds from banks. However, enterprises' behaviour towards bank loans was mainly determined by the interest rate policy implemented during the reform period. As nominal bank lending rates were lower than the inflation rate, the real cost of borrowing was negative (Cao 1990). Hence, enterprises sought as many bank loans as they could with little consideration of efficient utilization. Consequently, scarce capital resources were thinly spread across numerous enterprises by the decentralized banking system and were insufficient to meet demand. Non-price rationing occurred and, therefore, allocative efficiency in relation to bank loans is expected to have been poor.
- Capital inputs not under enterprises' control (the remaining planned investment) was allocated among enterprises in relation to their bargaining power with relevant government authorities. Therefore, enterprises' behaviour with respect to these capital inputs remained as it had been in the pre-reform period.
- As no basic ownership reforms were initiated, capital was still immobile between regions and enterprises. Hence, enterprises' ability to adjust their production scale to suit market conditions was largely restricted by their own accumulation of funds. Moreover, every enterprise, no matter whether it should have expanded its production capacity or not, had to implement more capital investment annually from its own accumulation according to the contract between enterprises and government authorities. As a result, industrial investment was spread more thinly among enterprises and a deterioration of scale efficiency happened in a considerable number of enterprises. Enterprises' scale efficiency would have thus been hardly improved.

Labour

The labour market was the least developed market in China's industrial sector. There was no real market wage rate to allocate labour: workers had *de facto* job tenure (White 1983, 1985, 1988). The ability of an enterprise's manager to use labour effectively was very limited. To minimize costs in relation to labour inputs, managers should have been able to relate the compensation of labour to its marginal revenue product. But their efforts were limited by their inability to retrench unnecessary workers and the strong pressure from workers for increases in their income in excess of their marginal productivity.

The "bonus incentive" policy was one of the most important policies implemented in an attempt to reform the labour and wage system. The Chinese government and economists were optimistically expecting that, if enterprises were allowed to issue bonuses to workers from retained profits, this would provide a greater incentive for workers to increase their work effort and improve their productivity, i.e., the enterprises' technical efficiency.

However, after a few years, the implementation of this bonus incentive policy merely resulted in a "competitive bonus spiral" across enterprises. Workers' bonus levels in individual enterprises were not differentiated according to achieved productivity gains, but they rather converged (Chinese Institute of Economic System Reform 1987; Dai and Li 1988). The "competitive bonus spiral" within enterprises was mainly due to the factor that managers were not given the power to change or adjust workers' basic wage levels. These continued to be regulated by central planning. Even in the area of workers' bonus level, managers' authority was strictly limited by government regulations. These were introduced mainly because of the "soft" nature of the financial constraints on enterprises and the undue pressure workers placed on enterprise managers to increase bonuses. Due to these factors, the effect of the "bonus incentive" policy on workers' effort may have diminished. Workers' income hence continued to lie outside the control of enterprises' managers in the sense that they could not

determine workers' income according to their marginal contributions to revenue.

The "competitive bonus spiral" which developed between enterprises resulted mainly from workers' pressure to increase remuneration. In so far as managers had autonomy to issue bonuses, it was inevitable that workers would pressure management to increase total wages not only to the highest level, but also to the highest level relative to other enterprises. Moreover, inadequate accounting and taxation systems that failed to audit enterprises' financial spending enabled managers to match their workers bonus level to that of other enterprises, regardless of productivity.[3]

Although the workers' bonus policy might have had a positive impact on workers' effort and hence on enterprises' technical efficiency, the consequent "competitive bonus spiral" led to an increase in the cost of labour. Factor allocation was thus distorted in the sense that labour, the most abundant resource in China, became relatively more expensive while the cost of capital was held at an artificially low level.

Two-tier Prices in Goods Market

The central goal of reforms in the price system advocated by the Chinese reformers was to deregulate the prices of most producer and consumer goods through the decentralization of the price administration from central to local agencies, to reduce the range of goods subject to State price controls and to diversify the pricing system encompassing a range of fixed, negotiated, floating and free market systems.

Iron and steel are basic industrial inputs for most industrial sectors. Thus, a nation-wide adjustment of iron and steel product prices, which had been kept artificially low under planning, would have had great impact on the cost of production throughout the economy, the price level of most of consumer goods and even the nation-wide pattern of income distribution. In 1984, the average prices of iron and steel products were increased by about

15 per cent (The Ministry of Metallurgical Industry of China 1985). The higher price level, however, was still too low to overcome excess demand. In 1986, the Chinese government planned to implement a comprehensive adjustment of the nation-wide price system. Its central concern was to raise the price of iron and steel products to a level that reflected the real cost of their production and cleared excess demand. As the effects of adjustments to prices for iron and steel products could not be predicted, only some consumer goods, such as wine and cigarettes, were chosen for the price reform implemented in 1987.

While iron and steel prices were still subject to the regulations of the central government, local authorities and enterprises were permitted to sell products under their control at prices up to an upper limit set by the State Price Bureau. This price level was, however, only 25 per cent higher than the planned price level (Tao 1988) and still not high enough to remove excess demand in the market. The average price of finished steel products set by the upper limit was about 1,100 yuan in 1988, but the prevailing market price was about 5,500 yuan. Non-state retailers could earn profit margins as high as 300 per cent from the re-sale of such products.

The upper price limit level set by the State Price Bureau for products controlled by local governments and enterprises greatly distorted the distribution of iron and steel products. While the upper price limit level was still far below the market equilibrium price, an enterprise's production was unlikely to respond to market demand. Corrupt relationships developed between local governments, enterprises and retailers, with illegal negotiations involving the distribution of supra-normal profits between suppliers and retailers. This corruption become known in China as *guan dao*, meaning the corrupt activities of bureaucrats who sold their controlled products to their *guanxi hu* (close friends or relatives) at planned or lower than market prices, so that these products could then be sold in the market at much higher prices. The resultant benefits were then shared between these bureaucrats and retailers. These practices also occurred in some enterprises,

which received benefits in the form of cash or goods from retailers who bought products from the enterprises at lower than market prices. The reported revenue from the sale of products could be concealed through the under-reporting of revenues and over-reporting of costs. In addition, commodity distribution was less likely to follow normal market channels because barter trade was encouraged by black-market activity.

Obviously, the iron and steel industry had a two-tier price system. While the State controlled a significant proportion of iron and steel production and distributed it at planned prices, a growing proportion of output was sold by enterprises at non-planned prices, either at floating or market prices. Hence, enterprises which were subject to less state controls were able to increase benefits to themselves either by selling more of their output at the floating price or by selling more of their controlled output at market prices. However, for enterprises which were subject to more state controls, benefits from the two-tier price system would be so limited that their production would adjust less to the market conditions. Enterprises in the same industry were thus not competing equally. Comparative cost advantages among enterprises in the industry were unlikely to play an important role in determining the distribution of production among enterprises. In other words, a convergence of cost-price ratios (the ratio used for defining scale efficiency) of enterprises in the industry could hardly be observed. Since the scale efficiency of enterprises is directly linked to their ability to adjust production scale according to their cost patterns and the conditions of market demand, the distortions caused by the two-tier price system limited the improvement of scale efficiency of enterprises and the convergence of cost-price ratios of enterprises.

IV. The Econometric Models for Analysis of Efficiency

The stochastic frontier model is used to estimate decomposed productive efficiencies (see Forsund et al. 1980 for a survey of different estimation methods). In the case of the estimation of technical efficiency, the principal advantage of this stochastic method is that the impact of factors under enterprises' control on technical efficiency can be distinguished from the impact of various external uncertainties. Enterprises in the iron and steel industry faced different production conditions according to their production location, their status in the bureaucratic hierarchy, their privileged access to supplies of production inputs and bank credit, and even their bargaining power with government in deciding on their shares from profit distribution. All these uncertainties external to enterprises were actually a reflection of market imperfections. As enterprises' performance could be affected by these external uncertainties, the impact of these influences should be netted out from enterprise-specific estimation of technical efficiency. As a result, estimated enterprise-specific technical efficiency will be a better indication of an enterprise's performance. The estimation of technical efficiency arrived at using the stochastic method, which distinguishes factors under enterprises' control (technical efficiency) from the random external effects (statistical random variables), thus ensures a proper estimation of technical efficiency. The resultant estimates of technical efficiency can be related to enterprises' efforts at utilizing production factors effectively. The effects of those uncertainties external to enterprises, such as market imperfections, on enterprises' productive efficiency can, however, be captured by the estimates of allocative and scale efficiencies.

Technical Efficiency

The following presentation of the econometric model which incorporates the existence of technical inefficiency is based on the work

of Aigner et al. (1977), Meeusen and Van den Broeck (1977), Forsund et al. (1980), Jondrow et al. (1982) and Kalirajan and Flinn (1983). As the detailed specification of the stochastic frontier model for estimating enterprise-specific technical inefficiency is well presented in these references, I will simply summarize the main structure of the model. It will be pointed out that enterprise-specific allocative and scale inefficiency can be directly calculated by using the parameters estimated from the stochastic frontier model and the observed variables.

Let the production function be represented by

$$y^* = f(x_1 \dots x_j \dots x_m) \tag{2}$$

where y^* is the maximum possible output an enterprise can produce using the inputs (x_j) in a technically efficient way. It is reasonable to assume that not all enterprises will be technically efficient and, consequently, not all enterprises will be operating on the industry's production frontier. The stochastic production frontier could then be represented by an unconstrained Cobb-Douglas production function:

$$\ln y_i = a_0 + \sum_{j=1}^{m} a_j \ln x_{ij} + u_i + v_i \tag{3}$$

where

y_i = actual output for the enterprise i and $y_i \leq y^*$;

u_i = an enterprise-specific technical efficiency parameter which captures the impact of factors under an enterprise's control on that enterprise's technical efficiency and $u \leq 0$ by taking a half normal distribution and then is iid $N(0, \sigma_u^2)$. That is, if $u_i = 0$, enterprise i operates with technical efficiency and if $u_i < 0$, with technical inefficiency; and

v_i = a random variable which captures the effect of the external uncertainties on an enterprise's production. The variable takes a normal distribution $N(0, \sigma_v^2)$.

In the above specification, enterprise-specific technical efficiency can be distinguished from the effects on efficiency of the external uncertainties that are beyond the enterprises' control (Forsund et al. 1980). The distinctive characteristic of the stochastic production frontier method is its ability to isolate technical efficiency, which is not observable, for each enterprise according to the conditional mean of u_i given (u_i+v_i). The density functions of u_i and v_i respectively can be written as:

$$f(u_i) = \frac{1}{\sqrt{\pi/2}}\frac{1}{\sigma_u}\exp\left(-\frac{u_i^2}{2\sigma_u^2}\right) \quad u_i \le 0 \tag{4}$$

$$f(v_i) = \frac{1}{\sqrt{\pi/2}}\frac{1}{\sigma_v}\exp\left(-\frac{v_i^2}{2\sigma_v^2}\right), \quad -\infty \le v_i \le \infty. \tag{5}$$

The joint probability density function (pdf) of (u_i+v_i), obtained using the convolution formula, can be written as:

$$f(u_i+v_i) = \frac{1}{\sqrt{\frac{\pi}{2(\sigma_u^2+\sigma_v^2)}}}\exp\left[-\frac{(u_i+v_i)^2}{2(\sigma_u^2+\sigma_v^2)}\right] \left\{1 - F\left[(u_i+v_i)\left(\frac{\sigma_u}{\sigma\sigma_v}\right)\right]\right\} \tag{6}$$

where, $F(\cdot)$ is the cumulative distribution function of the standard normal random variable. Specifying:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$

$$\lambda = \frac{\sigma_u}{\sigma_v}$$

$$e_i = u_i + v_i.$$

The density function of y_i is

$$f(y_i) = \frac{1}{\sigma\sqrt{\pi/2}}\exp\left(-\frac{1}{2}\frac{e_i^2}{\sigma^2}\right)\left[1 - F\left(\frac{e_i}{\sigma}\lambda\right)\right]. \tag{7}$$

The likelihood function of the sample can now be written as:

$$L(y,h) = \prod_{i=1}^{n}\left[\frac{1}{\sigma\sqrt{\pi/2}}\exp\left(-\frac{1}{2}\frac{e_i^2}{\sigma^2}\right)\left[1 - F\left(\frac{e_i}{\sigma}\lambda\right)\right]\right] \tag{8}$$

where h is the parameter to be estimated from the maximum likelihood (ML) method and is equal to (a_j, σ, λ). The enterprise-

specific technical efficiency for each enterprise, TE, can then be estimated from the expected value of u_i:

$$E\left[\frac{u_i}{u_i+v_i}\right] = -\frac{\sigma_u\sigma_v}{\sigma}\left[\frac{f(\cdot)}{1-F(\cdot)} - \frac{e_i}{\sigma}\lambda\right] \tag{9}$$

$$TE = \exp(u_i)$$

where $f(\cdot)$ is the standard normal density function and both $f(\cdot)$ and $F(\cdot)$ are evaluated at $(e_i\lambda/\sigma)$. The estimate of u_i is obtained by replacing e_i in Equation (9) by the residual which is the difference between the estimated and the actual frontiers. Since u_i is defined as a non-positive random variable in the econometric model of Equation (3), the domain of the technical inefficiency parameter, $TE_i = \exp(u_i)$, will be within the range of 0 to 1. Accordingly, $TE_i = 1$ indicates the achievement of 100 per cent of potential production and hence, technical efficiency, and $TE_i < 1$ indicates the failure to achieve potential production and hence, technical inefficiency.

Allocative Efficiency

Allocative efficiency can also be estimated as:

$$MP_{ji} / MP_{1i} = W_j / W_1 \exp(\alpha_{j1})_i$$

taking logs and rearranging,

$$(\alpha_{j1})_i = \ln(MP_{ji}) - \ln(MP_{1i}) - \ln W_j + \ln W_1$$

or, using the estimated production parameters from the estimated production function,

$$(\alpha_{j1})_i = \ln(a_1/a_j) + \ln x_{1i} - \ln x_{ni} - \ln W_n + \ln W_1 \tag{10}$$

where

MP_{ji} = the marginal product of input x_j ($j = 2, \ldots, m$);

W_j = the price of input x_j;

$(\alpha_{j1})_i$ = the allocative efficiency parameter between input 1 and j for the observation of i and α is iid $N(\mu, \Sigma)$. If $\alpha_{j1} = 0$, enterprise i is allocatively efficient; if α < or > 0, then it is allocatively inefficient;

a_1 and a_j = the production parameters estimated from the above ML method.

Since all variables in the right-hand side of Equation (10) are economic variables and a_j and a_1 are available from the estimated stochastic frontier production function, allocative efficiency parameter $(\alpha_{j1})_i$ can then be directly calculated.

Scale Efficiency

Scale inefficiency can be defined as:

$$dC_i / dy_i = P \exp(\xi_i)$$

where

dC_i / dy_i = the marginal cost of production in enterprise i;

P = the price of y_i;

ξ_i = the scale inefficiency parameter for enterprise i and is iid $N(0, \sigma_\xi^2)$. If $\xi_i = 0$, enterprise i is scale efficient; if $\xi_i < 0$, it is scale inefficient in the sense that production is less than the optimal output level; and if $\xi_i > 0$, the enterprise is also scale inefficient but in the sense that production is greater than the optimal output level.

By using the parameters estimated from the production function and the parameters of technical efficiency (in the domain $0 \leq u_i \leq 1$) and allocative efficiency, scale efficiency can be derived as

$$\xi_i = -\ln a_1 + \ln W_1 + \ln x_1 - \ln Y - \ln P - \Sigma_j a_j(\alpha_{j1})_i / \Sigma_i a_i + (u_i + v_i) / \Sigma_i a_i \quad (11)$$

$$i = 1, \ldots n; j = 2, \ldots n$$

The above specification of scale efficiency is based on technically efficient output and allocatively efficient input (see Kumbhakar et al. 1989 for details of the derivation). Hence, it actually defines scale efficiency as being conditional on technical and allocative efficiency. Since only the technically efficient output and allocatively efficient input levels are considered in the estimation of scale efficiency, the estimates of scale efficiency will

have distinctive economic meaning alongside those for technical and allocative efficiencies.

Equations (9), (10) and (11) form the system of equations employed for incorporating technical, allocative and scale inefficiencies into a profit-maximizing stochastic frontier framework.

V. The Variables Used in the Estimation and an Explanation of the Data Used

Enterprise level data for the Chinese iron and steel industry for the years 1980, 1985 and 1988 were used in the estimation as these years were the most crucial in the past decade of reforms. The data are taken from *Quanguo gongye pucha ziliao* (Nation-wide Industrial Investigation Documents) (Nation-wide Industrial Investigation Office, State Economic Commission of China 1987), *Zhongguo Gangtie gongye nianjian* (The Yearbook of Chinese Iron and Steel Industry) (The Ministry of Metallurgical Industry of China 1986 and 1989). The estimation from data for 1980 was used to represent the situation in the early stage of the economic reforms. As few reform measures had been implemented by 1980, it could be expected that enterprises' behaviour and performance were still mainly influenced by the traditional planned system.

The year 1985 was chosen because, in 1984, China's State Council issued provisional regulations expanding the autonomy of enterprises. The regulations authorized enterprises' decisions on pricing, production levels and sales, investment planning, internal organization, personnel management and the disposition of wages and loans. It could be expected that these regulations had an impact on enterprises' performance one year later, that is, by the end of 1985. The year 1988 was chosen because substantial reform measures have not been implemented since then. The estimations from the data in 1985 and 1988 are compared with those from 1980. Hence, it is possible to investigate whether there was any systematic change in enterprises' efficiency during the reform period.

Ninety-nine different scale enterprises were chosen as the sample population. The total annual gross output value of the 99 enterprises amounted to 81, 79 and 78 per cent of the total gross output value for the whole industry for 1980, 1985 and 1988 respectively. This sample is used as a proxy to represent the situation in the whole industry.

In the following analysis, the observations are separated by size, based on the magnitude of their gross output value. Enterprises which had annual gross output values above 300 million yuan were taken to be the sub-group of large-scale enterprises. Enterprises which had annual gross output values between 50 to 300 million yuan were medium-scale enterprises. The remaining enterprises comprised small-scale enterprises.

The variables used in the estimated production function are gross output (at 1980 constant price), fixed capital, labour force, working capital and enterprise-size dummies. Gross output is the dependent variable and the remaining variables are independent.

The independent variables cover almost all production factors directly used in production. Fixed capital stock and labour force are the standard production factors in most production function analyses. Since data for cost of industrial materials are not available, working capital is used as a proxy. In the Chinese iron and steel industry, more than 70 per cent of working capital has been used for purchasing industrial materials. The pattern of working capital may hence largely reflect the pattern of cost of industrial materials.

Only productive capital and labour force are used in this study. Hence, the non-productive capital and labour that are usually mixed together in the Chinese statistics are deleted from the analysis. Effort is also made to derive the fixed capital for each individual enterprise from the base-year fixed capital and the deflated investment (see Chen et al. 1988b for details of this methodology).

The enterprise-size dummy needs more explanation. As far as cross-sectional analysis is concerned, the difference in enterprise size can sometimes have a substantial effect on an enterprise's

productivity (Van den Broeck 1988). This is particularly relevant to iron and steel industry. This industry is well known as having substantial economies of scale (Isard 1949; Cockerill and Silberson 1974; Gupta and Fuss 1979; Crandall 1981; Hilly 1989). By international standards, the minimum efficient scale of an integrated steel enterprise should be, at least, at two million tonnes of finished steel per year and of non-integrated enterprise at one million tonnes (Scherer 1974; Scherer and Ross 1990). However, only 10 out of more than 100 iron and steel enterprises in the Chinese industry achieved one million tonnes of finished steel in 1980. Concern is thus on those small enterprises which have been operated under the minimum efficiency scale by international standards. The effect of enterprises' scale is captured directly by the enterprise-size dummies. Specifically, the following estimation model makes medium-scale enterprises the benchmark and contains dummy variables for large- and small-scale enterprises. It is then expected that the cost advantage of the large-scale enterprises due to economies of scale will be captured by a positive coefficient for their size dummy variable, and, conversely, the cost disadvantage of the small-scale enterprises due to the lack of economies of scale will be captured by a negative coefficient of their size dummy variable. If this is the case, the finding from the time series estimation of a loss of scale economies will be supported by the cross-sectional analysis.

It should be noted that the estimate of scale effects from the enterprise-size dummy is somewhat different from the estimate of enterprise-specific scale efficiency defined by Equation (11). Enterprise-specific scale efficiency as defined by Equation (11) was derived from comparison of output price and marginal cost. By equating marginal cost to output price, every enterprise has a specific optimal production scale. Hence, an enterprise in an industry might be relatively more efficient in scale than other enterprises but might still not be able to achieve its full-scale economy potential. The enterprise-size dummy captures enterprises' relative efficiency in scale, but the estimate of scale efficiency from

Equation (11) indicates whether an enterprise has achieved its optimal scale.

In the derivation of allocative efficiency, the cost of working capital and fixed capital are compared with the cost of labour. Since reforms in industrial finance in 1984, most working capital has been in the form of bank loans, which are subject to repayment and carry a cost in the form of interest. Thus, there is an opportunity cost to enterprises for use of their working capital. As enterprises retained part of their profit under the contract system, and continuously added new investment to their fixed capital stock from retained profits, the fixed capital stock might gradually have come more or less under the control of enterprises. This is because enterprises' total capital formation would have been adjusted towards the realization of profit maximization. Fixed capital stock might have become more or less sensitive to enterprises' output as an increasing part of fixed capital stock came to have an opportunity cost for enterprises. The estimates of allocative efficiency allow empirical investigation of the above situation.

The estimates for allocative and scale efficiencies are sensitive to the input and output prices used in the estimation. Considering that factor and goods markets were seriously distorted in China, actual input and output prices and hypothesized market clearing prices were used in the estimation of allocative and scale efficiencies. Comparative analysis can therefore be conducted using the different price-based estimates. The hypothesized market clearing prices for the average allocative efficiency of all sample enterprises were estimated by an iteration process: different prices were tried, and the set finally chosen was that under which the average allocative efficiency of the 99 enterprises became zero, that is, on average allocatively efficient. As small-scale enterprises are hypothesized to be the most scale inefficient in the iron and steel industry, the hypothetical market clearing price for scale efficiency is simulated for small-scale enterprises. Under the simulated output prices, small-scale enterprises on average are scale efficient, that is, their marginal cost equals the hypothetical prices. Although this method is more or less an arbitrary means of identifying a correct set of the potential market clearing prices, it can, nevertheless, correctly indicate whether the actual input and output prices were lower or higher than the potential market clearing prices. Hence, the policy implications of the estimates of allocative and scale efficiency are easily verified.

The actual price for working and fixed capital is taken from loan rates set by the China's Industrial and Commercial Bank and were 4.8 per cent for 1980, 7.3 per cent for 1985 and 7.8 per cent for 1988. The average annual income of workers was calculated from workers' average wage. Average welfare expenditure in the industry was used as a proxy for the cost of employing labour. Considering that "bonus spiral" activity among enterprises led to a more or less equivalent income level among workers within an enterprise as well as across enterprises, this industrial average income is a reasonable proxy for the cost of additional labour for each enterprise. These annual labour costs were 1,200 yuan, 1,550 yuan and 2,200 yuan for 1980, 1985 and 1988 respectively. The actual output price used in the estimation is the weighted unit value of pig iron, crude steel and finished steel from the large-scale enterprises. This unit value is taken as a base price that every enterprise should have been able to charge for its output. It is used because the large-scale enterprises were subject to greater government planning and proportionately more of their output was sold at lower, planned, prices. Thus, the weighted unit value of gross output from large-scale enterprises was the lowest in the industry.

VI. The Analysis of Empirical Results

The stochastic production frontier, Equation (3), was estimated using the maximum likelihood (ML) method from the programme "Frontier" (Coelli 1991). The programme was specially designed for the estimation of frontier production function by the ML method. The estimation procedure involves three steps: first, the calculation of ordinary least-square estimates (OLS); secondly, a grid search involving the value of γ ($\gamma = \lambda/(1+\lambda)$) and a_0 (intercept term) along with adjustment of the estimate of σ^2;[4] and thirdly, the estimates from grid search are used as starting values for an iteration procedure to approximate the maximum likelihood estimates. The coefficient η is also provided by the programme as the reference for testing the significance of time-varying technical inefficiencies of the observations. If η is statistically significant, it indicates that technical inefficiencies of the observations are changing over time. Moreover, $\eta > 0$, $\eta = 0$ and $\eta < 0$ in the estimated model indicate that the estimated technical efficiency of enterprises over time tends to increase, remain constant or decrease respectively. The statistic model used in the programme is in Battese and Coelli (1991) and will not be presented here for simplicity.

There are two reasons for using ML estimation. First, OLS of the production function (Equation 3) provides an unbiased estimate of the k x 1 vector of production elasticities, a_i, but not of the intercept, a_0, due to the non-zero expectation of (v_i+u_i). The ML method outlined above can provide an unbiased estimate for a_0. Secondly, the OLS estimate of the variance, denoted by σ^2_{OLS}, is often an under-estimate of the sum of the variances of V_i and U_i, σ^2. Thus, when the grid search is carried out (over $0 < \gamma < 1$ and $-2\sigma_{OLS} < \mu < 2\sigma_{OLS}$) the values of the intercept and variance parameters are adjusted accordingly. The "Frontier" programme was chosen because the iterative method used for approximating the ML estimates, the Davidon-Fletcher-Power method, is one of the more successful Quasi-Newton methods (Himmelblau 1972).

The estimation used panel data of 1980, 1985 and 1988 and the estimation results are reported in Table 1. From Table 1, it can be seen that the coefficients of all observable variables, fixed capital, working capital and labour force, have reasonable positive magnitudes and are statistically significant. The parameters for enterprise-scale dummy variables in particular are statistically significant and have the expected signs, that is, the large-scale enterprise dummy has a positive sign and the small-scale enterprise dummy has a negative sign. This may suggest that, due to their economies of scale, the large-scale enterprises had greater

total factor productivity. On the other hand, the lack of economies of scale in the small-scale enterprises had a negative impact on their total factor productivity.

Table 1 Maximum likelihood estimation results (dependent variable = gross output and observation numbers = 99 x 3)

Coefficients	Independent variables	Estimates
a_0	Constant	2.24
		(20.66)[(1)]
a_1	Fixed capital	0.32
		(6.13)
a_2	Working capital	0.33
		(6.40)
a_3	Labour	0.11
		(2.70)
a_4	Dummy	0.38
	(Large-scale enterprises)	(5.99)
a_5	Dummy	-0.20
	(Small-scale enterprises)	(-3.68)
$\gamma^{(2)}$		0.94
		(122.97)
$\sigma^{2(2)}$		0.57
		(7.24)
η		0.15
		(7.78)
Log-likelihood		-60.73

Notes: (1) Figures in brackets are t-ratios, and all are statistically significant at the 5 per cent level.
(2) σ_u and σ_v in Equation (9) can be calculated using the formula $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \lambda/(1 + \lambda)$ (Jondrow et al. 1982, Battese and Coelli 1991).

It should also be pointed out that the parameters of γ and σ^2 of the ML estimation are statistically significant and the log-likelihood value is high enough to surpass the critical value. η is positive and statistically significant from zero which indicates the overall improvement of technical efficiency of the sample enterprises over time. Hence, the ML estimation is very reliable. Emphasis will now be placed on the explanation of the estimates of technical, allocative and scale efficiencies.

Technical Efficiency

As stated above, an enterprise is said to be technically efficient if the estimated technical efficiency coefficient is 100 per cent and technically inefficient if the coefficient is less than 100 per cent. This means that, if an inefficient enterprise can utilize its production factors as effectively as an efficient enterprise, it should be able to increase its current output to the output level that an efficient enterprise could achieve using the same factor inputs without increasing its current factor inputs. The average technical inefficiencies of different scale enterprises calculated from the estimates of individual enterprises are presented in Table 2.

Table 2 Average technical efficiency among different size enterprises, 1980, 1985, 1988

	1980	1985	1988
All sample enterprises	0.46	0.49	0.53
In which			
Large-scale enterprises	0.55	0.59	0.62
Medium-scale enterprises	0.47	0.51	0.55
Small-scale enterprises	0.25	0.29	0.33

There was an obvious improvement in technical efficiency in all enterprises over the reform period. This finding supports the hypothesis that, to maximize profits, enterprises utilized their production factors more effectively and improved their technical efficiency. However, the average technical efficiency of all enterprises in 1988 was only 0.53 and thus low. This indicates that the improvement in enterprises' technical efficiency over the reform period was not sufficient to move enterprises' output close to their potential output level.

The obvious differences between the technical efficiency of different size enterprises should be noted. In the three years studied, while medium-scale enterprises' technical efficiency levels were at the average level of all enterprises, the large-scale enterprises' levels were above the average and the small-scale enterprises' levels were well below. This is a clear indication of economies of scale in iron and steel, that is, large-scale enterprises could achieve their potential efficient output more easily by utilizing their production facilities more effectively than could small-scale enterprises.

The technical efficiency gap between different-scale enterprises is still a serious concern for the development of the Chinese iron and steel industry although the improvement in technical efficiency of all enterprise groups during the reform period was impressive. Under the protection of local governments and especially with the advantage of being able to sell a larger portion of their products at higher market prices, some of the local medium- and small-scale enterprises were still able to increase their profit margin even though they had an obvious technical and, hence cost, disadvantage in production expansion. Table 3 compares the more technically efficient enterprises, enterprises within the category $0.80 <$ technical efficiency < 1.00, with the least technically efficient enterprises, those within the category $0.20 <$ technical efficiency < 0.40, in terms of their growth rates and ratio of profit to gross output. The most technically inefficient enterprises had a higher output growth rate and, more importantly, they had a slightly higher ratio of profit over gross output. This suggests that the technically inefficient enterprises had an advantage in charging higher prices for their product or in obtaining more inputs at controlled prices, or both. Otherwise, their profit margin would have been lower.

Table 3 Growth rate and ratio of profit to output for enterprises with different levels of technical efficiency[1]

	Enterprises with 0.80 < technical < 1.00 efficiency	Enterprises with 0.20 < technical < 0.40 efficiency
Number of enterprises	12	34
Growth rate (%)	0.19	0.25
Profit/gross output (%)	0.23	0.25

Sources: The Ministry of Metallurgical Industry of China (1986 and 1989).
Note: (1) Enterprises' average rate of gross output growth between 1985 and 1988.

Allocative Efficiency

Equation (10) was used to calculate allocative efficiency. According to this equation, an enterprise is said to be allocatively efficient if the estimate of α_{ij} for the relevant inputs i and j is 0 and allocatively inefficient if the estimate is not equal to 0. This means that enterprises which are allocatively efficient have chosen an input combination such that the ratio of the marginal productivities of inputs is equal to the ratio of the prices of these inputs. In other words, costs to enterprises which are allocatively efficient cannot be further reduced by substitution between production factors.

The economic implications of negative or positive values of estimated allocative efficiency can be explained by reference to the inputs which are compared. Using a comparison between labour and fixed capital as an example, Equation (10) becomes:

$$MP_K/MP_L = r/w \exp(\alpha)$$

where MP_K and MP_L are the respective marginal products of fixed capital and labour, r is the interest rate for fixed capital, w is the wage rate, and α is the estimate of allocative inefficiency.

The economic implication of a negative α can be explained as follows. Given r and w, an enterprise can only change MP_K and MP_L to correct the inequality between marginal product of input and input price and achieve allocative efficiency. Hence, MP_L, the marginal product of labour, must be higher than MP_K, the marginal productivity of capital. In other words, capital is being over-utilized and labour under-utilized (Kumbhakar et al. 1989:597). The rational adjustment of factor combinations would then use proportionately less capital relative to labour so that an enterprise could take advantage of the higher marginal product of labour. Costs can accordingly be reduced. The opposite conclusion can be drawn regarding a positive value of the estimates for the allocative inefficiency parameter within the above framework. However, the distorted prices of inputs should also be considered as one of the causes for the allocative inefficiency. If MP_K and MP_L are given, allocative efficiency can be achieved either by increasing the interest rate, r, or decreasing wage level, w. Hence, the allocative inefficiency of enterprises, as described above, may be due to distortions in factor market prices, encouraging over-utilization of one factor relative to another. Therefore, implications of the estimates derived for allocative inefficiency must be carefully considered depending on the likely causes.

In the estimations of allocative efficiency presented below, labour and wages were chosen as the numerators of Equation (10) to enable comparison with the other inputs: fixed capital and working capital respectively. The average allocative efficiency of different-scale enterprise groups is calculated from the estimates of individual enterprises' allocative efficiency parameters and is reported in Table 4. The consistent negative signs for the estimates of the allocative efficiency parameters clearly indicate a general pattern of distortion in Chinese factor markets: workers were over-paid and capital costs were under-valued.

Table 4 Average allocative efficiency between labour and fixed and working capital for different-scale enterprise groups, 1980, 1985, 1988

	1980	1985	1988
Allocative efficiency between labour and fixed capital			
All sample enterprises	-0.77	-0.60	-0.65
In which			
Large-scale enterprises	-0.60	-0.44	-0.44
Medium-scale enterprises	-0.80	-0.62	-0.67
Small-scale enterprises	-0.83	-0.64	-0.72
Allocative efficiency between labour and working capital			
All sample enterprises	-1.18	-1.07	-1.09
In which			
Large-scale enterprises	-1.19	-1.08	-1.07
Medium-scale enterprises	-1.19	-1.07	-1.08
Small-scale enterprises	-1.16	-1.05	-1.17

However, an improvement in allocative efficiency can be observed between 1980 and 1985. The average allocative efficiency of all sample enterprises changed from -0.77 to -0.60 for the labour/fixed capital comparison and from -1.18 to -1.07 for the labour/working capital comparison over this period. This indicates that the enterprises had become more sensitive to economizing the use of fixed and working capital in production.

The key to understanding this trend is the changing nature of the sources of investment for upgrading and innovation. These contributed to the newly established fixed capital and working capital. Reforms in industrial financing had barely begun in 1980. Finance for investment for upgrading and innovation was channelled mainly through government planning. It would have been rational for enterprises to try to obtain more investment funds

from government authorities as the cost of investment to enterprises was actually negligible. However, following 1984, enterprises had to provide a considerable part of investment funds from their own accumulated revenue. Enterprises' behaviour towards the use of this investment could be expected to change. Clearly, enterprises should have considered the opportunity cost of this investment as the same source of investment could be used for other purposes, providing returns at full market value. Therefore, enterprises should have tried to maintain the marginal product of this investment at the same level as its opportunity cost. The improvement in allocative efficiency of fixed capital was reflected by the changed nature of this investment during the reform period.

As far as working capital is concerned, interest rate charges on enterprises' working capital began in 1984 and provided enterprises with an incentive to use working capital more effectively compared with the situation in 1980, when working capital was mainly provided freely through government planning sources.

Nevertheless, it must be noted that allocative efficiency between labour and capital was still poor in 1985 and, more importantly, the improvement in average allocative efficiency for all sample enterprises over the period 1980-1985 was replaced by a deterioration of allocative efficiency between 1985 and 1988 (although, for the large-scale enterprise group, the level of average allocative efficiency of fixed capital over labour remained the same in 1988 as in 1985 and its level of average allocative efficiency of working capital over labour improved slightly). As indicated in Table 4, parameters for average allocative efficiency of labour/fixed capital and labour/working capital of all sampled enterprises changed from -0.60 to -0.65 and from -1.07 to -1.09 respectively between 1985 and 1988. This finding suggests that the enterprises' ability to improve allocative efficiency was largely restricted by the distortions existing in factor markets.

A considerable part of enterprises' fixed capital was inherited from the pre-reform period and enterprises paid no financial cost for its use. This contributed to the capital-biased allocative inefficiency. More importantly, the virtually zero cost plan-allocated fixed capital investment was still provided during the reform period. Even if interest rates were charged for these investment funds, they were low or even negative in real terms, making this investment a "free gift" to enterprises.

Biased capital investment in the iron and steel industry was encouraged by self-reliant regional development. Regional segmentation of the industry increased during the reform period, and the lack of reforms regarding ownership of industrial assets continued to restrict capital mobility between regions, sectors and enterprises. Every region attempted to ensure its own iron and steel production capacity. Because the basic capital investment for an iron and steel enterprise was usually larger than that for other enterprises, huge amounts of capital had to be invested by each region into these enterprises. Moreover, other industrial resources, such as coal and iron ore, were not equally distributed across regions and, more importantly, were scarce relative to the number of enterprises. Therefore, there were always enterprises which could not maintain normal production because of the shortage of industrial materials. On the one hand, working capital had to be over-used to store the industrial materials that were in short supply and, on the other hand, the working capital of these enterprises had a low marginal productivity.

Although the reforms provided banks with the right to charge interest rates for working capital, banks failed to set interest rates according to an economic rationale and thus stimulate enterprises to operate efficiently. The interest rate that banks charged remained subject to mandatory administration from either the central government or local governments. The interest rate on working capital was thus also low and did not reflect the shortage of its supply. According to Chinese statistics (State Statistical Bureau of China 1990), the annual inflation rate for industrial material in 1988 was 12 per cent. Compared with the nominal interest rate for working capital, of 9.6 per cent, banks incurred a net cost by providing enterprises with working capital. Enterprises benefited by borrowing as much working capital as they could from

banks. As the cost enterprises faced for working capital was essentially negligible, it was rational for enterprises to use working capital even if its marginal product was low. This factor, and the shortage of industrial materials outlined above, contributed to poor utilization of working capital and hence substantially higher negative magnitudes for the estimated parameters of allocative efficiency from working capital. These can also explain why the simulated market interest rates for working capital are very high (Table 5).

The economic reforms failed to create a labour market in the industrial economy. Workers retained their job tenure. Because of the lack of a well functioning labour market, managers could not easily decide individual workers' bonus levels through reference to a market determined rate. Instead, workers put great pressure on managers to increase the level of bonuses up to the highest level observable in other enterprises so that a "competitive bonus spiral" took effect. During the period 1985 to 1988, the share of the wage bill in total net value of output increased from 18.7 per cent to 23.6 per cent in 1988 (Nation-wide Industrial Investigation Office, State Economic Commission of China 1987 and The Ministry of Metallurgical Industry of China 1988, 1989). This indicates that the real cost of labour increased over the late reform period due to the increase in the real wage level of workers. Hence, the higher wage rates of 1988 were one of the key factors in the deterioration of allocative efficiency.

Table 5 Comparison between actual factor prices and simulated market-clearing factor prices, 1980, 1985, 1988

	1980	1985	1988
Wage rate (Yuan)			
Actual	1200	1500	2200
Simulated	600	700	920
Interest rate for fixed capital (%)			
Nominal interest rate	4.3	7.3	7.8
Simulated interest rate	14.0	14.5	23.0
Inflation rate	6.0	8.8	18.5
Real interest rate	0.6	-0.5	-3.3
Simulated market clearing real interest rate	8.0	7.9	4.5
Interest rate for working capital (%)			
Nominal	4.3	7.3	7.8
Simulated	36.0	39.5	40.0
Inflation rate	6.0	8.8	18.5
Real interest rate	0.6	-0.5	-3.3
Simulated market clearing real interest rate	30.0	30.7	21.5

Sources: Actual wage is taken from The Ministry of Metallurgical Industry of China (1985-1989); Nation-wide Industrial Investigation Office, State Economic Commission of China (1987). Simulated wage rate is from the estimation. Nominal interest rate is from China People's Bank (1987/10:9, 1989/4:10, 1990/1:22). Inflation rate is from World Bank (1991). The real interest rate and simulated market clearing real interest rates are calculated as the differences between nominal interest rate and inflation rate and simulated interest rate and inflation rate respectively.

To shed more light on the extent of distortions in Chinese industrial factor markets, the market clearing prices of capital and labour have been simulated according to the structure of enterprises' marginal factor productivity. The simulation results are compared with the actual factor prices in Table 5. It is clear that a much higher interest rate and a lower wage level would have been necessary to achieve the average allocative efficiency of enterprises in the industry. Also, the inflation rates in the three years are also provided in Table 5. From the inflation rates, the real interest rate and the simulated market clearing interest rate can be calculated as the differences between nominal interest rates and inflation rates and simulated interest rates and inflation rates respectively. It can be seen that the real interest rates are almost zero in 1980, and negative in 1985 and 1988. This indicates that there was no real cost at all for enterprises to obtain loans from banks. As mentioned above, the simulated interest rates for working capital were very high. Compared to the rates for fixed capital, the higher rates for working capital could be attributed to their short-term nature.

Scale Efficiency

Equation (11) was used to calculate the parameters of scale efficiency. According to the formulation, a negative value of the scale efficiency parameter for an enterprise indicates an excess of output price over marginal cost. This implies that such enterprises are operating below their optimum production scale. On the other hand, a positive estimate of the scale efficiency parameter indicates an enterprise producing marginal cost above output price and operating above its optimal production scale.

Since the analysis involves a period of almost ten years (1980-1988), the estimated scale inefficiencies are treated as long-term inefficiencies of enterprises. Marginal cost curves of enterprises are hence long-term. In the long term, the marginal cost curve is an upward sloping curve which intercepts the price line only once. This means that there is a unique optimal scale of production for the enterprise at which the marginal cost of the enterprise is equal to the prevailing market price (McCloskey 1982; Call and Holahan 1983). Following the criterion of scale efficiency, enterprises producing over their optimal scales (their marginal costs are larger than the prevailing price) should reduce their production and enterprises producing under their optimal scales (their marginal costs are less than the prevailing price) should increase their production. It should be pointed out that the analysis of scale economies or optimal scale is usually based on the long-term situation of enterprises. However, if the short-term situation of enterprises is considered, one may observe a U shape marginal cost curve of enterprises. The change of an enterprise's production in regard to the relationship of its short-term marginal cost curve and prevailing price should be the same as that in the long-term situation if only the section of upward sloping curve of the short-term marginal cost curve is considered. But if the section of downward sloping curve is considered, enterprises should always expand their output no matter what the prevailing market price is. In other words, whether marginal cost is less or larger than the prevailing price is irrelevant in deciding the change of scale of the enterprise's production if the section of downward sloping curve is considered. This is why the analysis of scale efficiency which compares marginal cost with price usually considers the long-term marginal cost curve only, simply because the comparison between short-term marginal cost curve (the section of downward sloping curve) and price does not make any sense. Therefore, the estimated scale inefficiencies should be explained in terms of long-term marginal cost rather than short-term marginal cost of enterprises. The limitation of analysis of scale efficiency should then be noted because the estimated long-term scale inefficiencies of enterprises may not reflect the adjustment of short-term marginal cost of enterprises.

Price discrimination between different-scale enterprises under the two-tier price system and its impact on enterprises' scale efficiency is captured by estimates based on two different kinds of output prices. The weighted unit value of iron and steel products from large-scale enterprises, as mentioned before, will be used as the base price, i.e., that which every enterprise should be able to charge. A hypothetical market clearing price will be decided for the small-scale enterprises. More specifically, if small-scale enterprises charge this hypothetical price, their marginal cost on average will equal the hypothetical price and hence on

average scale efficiency would be achieved. Since most small-scale enterprises were profitable over the period studied, this hypothetical price would be the bench-mark price which the small enterprises would have to charge. It is then possible to compare this benchmark price with the base price and obtain an indication of the extent of price distortion. The estimates are reported in Table 6.

Table 6 Average scale efficiency of different size enterprise groups, 1980, 1985, 1988

	1980		1985		1988	
	P(1)	MP(2)	P	MP	P	MP
Large-scale enterprises	-0.17	-0.42	-0.21	-0.41	-0.10	-0.63
Medium-scale enterprises	0.22	-0.04	0.16	-0.04	0.27	-0.26
Small-scale enterprises	0.26	0.00	0.19	0.00	0.49	0.00

Notes: (1) Estimates from weighted unit value of iron and steel products from large-scale enterprises.
(2) Estimates from the hypothetical market clearing price at which small-scale enterprises would on average achieve scale efficiency.

Considering the average scale efficiency of each enterprise group over the studied period, the estimates based on the base price for iron and steel in Table 6 indicate that, on average, the large-scale enterprises were operating under their optimal scale. That is, their marginal cost was lower than the base price of output. On the other hand, the medium- and small-scale enterprises on average were operating above their optimal scale. That is, their average marginal cost was higher than the base price of output.

Which factors enabled medium- and small-scale enterprises to operate at levels above their optimal scale and produce at marginal cost that was greater than the output price? The estimates based on the hypothetical market clearing prices necessary for the small-scale enterprises on average to achieve scale efficiency provide some clues into this problem. The hypothetical prices were 580, 510 and 1100 yuan for 1980, 1985 and 1988 respectively and the base prices were 321, 324 and 326 yuan in 1980, 1985 and 1988 respectively. The divergence between the two different types of prices was very great, especially in 1988. The implication of these estimates is clear. If small-scale enterprises had charged higher market prices, they would have avoided economic losses. If medium-scale enterprises had charged such prices, they would even have earned economic profits.

The absolute difference between the scale efficiency of large-scale enterprises and that of small-scale enterprises may suggest that the price distortion in goods market may have provided chances for the expansion of medium- and small-scale enterprises in the Chinese iron and steel industry. If the price distortion can be reduced, one may predict that the large-scale enterprises with obvious economies of scale (lower marginal cost) could capture more production share from the medium- and small-scale enterprises. This redistribution of production share could then improve scale efficiency in the Chinese iron and steel industry.

VII. Conclusion

Technical efficiency for most enterprises was found to have improved over the economic reform period. This basically supports the hypothesis that, as various incentives, such as profit retention and bonus policies, were provided to enterprises and workers, they utilized production factors more effectively and achieved higher productivity. The large-scale enterprises are found to be relatively more technically efficient than medium- and small-scale enterprises.

The estimates of allocative inefficiency indicate that factor markets were distorted with labour being over-paid and capital under-paid. Nevertheless, allocative efficiencies between all studied inputs were also found to have improved slightly over the reform period. While this finding seems to support the hypothesis that enterprises should seek to economize on their production factors and thereby improve their allocative efficiency, caution should be paid to the absolute level of allocative inefficiency in the estimated reform years and the trend of deterioration of allocative efficiency in the late reform years (1985-1988). A more realistic explanation of the estimated result is that the ability of enterprises to improve their allocative efficiency was restricted by distortions in factor markets. Moreover, increasing distortion in factor markets would lead to the failure of enterprises to rationalize their use of production factors. The simulation for the hypothetical situation of average allocative efficiency of all sample enterprises indicates that capital should have been valued much higher, and labour, on the other hand, should have been valued much lower. Particularly, the interest rate for working capital should have been much higher than the prevailing rate. Hence, the policy implication of these results is that giving enterprises the right to maximize profits is a necessary but not a sufficient condition for optimal resource allocation. The sufficient condition is to create functioning factor markets which will give correct market signals to enterprises.

From the estimates of scale inefficiency based on the base prices, large-scale enterprises were found to operate below their optimal scale and medium- and small-scale enterprises were found to operate above their optimal production scale. From the estimates based on the hypothetical market clearing prices for small-scale enterprises, it is revealed that medium and small enterprises should have charged much higher prices for their output to make profits. The existence of the substantial difference of scale inefficiency between different enterprise groups may hence be largely due to the price distortion in goods market.

Notes

1. Kornai (1980) argued that typical plants in centrally planned economies were not normally restrained by fears of loss or failure of production because their production was externally decided by a central plan. The central decision makers took all responsibility for ensuring input supply to support the production and commercial distribution of the final products. Therefore, the survival of plants in a centrally planned economy was hardly contingent on their ability to cover all their costs out of their sales proceeds since grants, subsidies and tax favours could be negotiated to fill the gap. The basic motivating force for plants was a strong quantity drive, that is, an incentive to increase output as far as possible given available resources. In relation to investment, there was an incentive to initiate and undertake investment projects to expand the scale of operation by seeking more favourable offers from a central economic plan, without any concern for whether this expansion produced net economic benefits for the country.
2. Some studies (Chen et al. 1988a; Dollar 1990; Li 1990; Lau and Brada 1990) indicate that the total factor productivity of the Chinese industrial sector improved during the reform period. However, some studies (Lardy 1987; Du et al. 1990) found that the productivity gains due to the reforms were rather poor and that they even deteriorated in some years. Different methodologies used for these studies may be the cause of this divergence. But it might also be that all these estimates are more or less biased in favour of one of the two effects discussed in the text. The optimist estimates were biased towards the effects on the transition in plants' behaviour; the pessimist estimates, towards the effect of imperfections related to the Chinese market mechanism.
3. Numerous studies have been conducted on the workers' role in determining plant's investment patterns in Yugoslav labour-managed plants (Bonin 1985; Mitchell 1989). The main finding was that workers in labour-managed plants could not recover the principal remaining on self-financed investment upon leaving the plant; therefore, all benefits from self-financed investment must accrue through increased salaries during the workers' tenure with the plant. This requirement gives rise to a horizon problem, which refers to the relative unwillingness of workers who are nearing the end of their association with the plant to retain earnings for self-financed investment. The effect of the behaviour of Chinese workers on plant's investment is very similar to that of the labour-managed plants' workers in the sense that Chinese workers only take the income increase in the contracted period as their own benefit but treat the plant's long-run profitability as something beyond their control and even as a contrary factor to the increase of their income.
4. This is the case when the restricted mode with μ set to zero is estimated. When this restriction is relaxed, the grid search involves values of γ and μ along with adjustment of estimates for a_0 and σ^2.

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7

Growth, Efficiency, and Structure Change in Chinese Manufacturing Industries in the 1980s

Zheng Yuxin

In a recent paper (Jefferson et al. 1992) on the measurement of productivity changes in the state-owned and the collective industries, we concluded that there seemed to be an increasing trend toward industrial productivity as well as a convergence of productivity between the state-owned and the collective industries in the 1980s. This chapter is a further study to explore the productivity and the sources of growth at a disaggregated level. This study is limited to the manufacturing industry which is the most important sector in the national economy; and in doing so, the problem of price distortions induced by the low prices of primary products can be avoided to some extent. The manufacturing industry is divided into 37 sectors (see Table 1). The classification of the manufacturing industries in this chapter is consistent with the international standard. The sectoral analysis will help us to discover information lost or obfuscated at the aggregate level; furthermore we can have a better understanding of the sources of growth and productivity.

Table 1 Output elasticities of input of Chinese manufacturing and its subsectors

		α_{Li}		α_{Ki}		α_{Xi}	
		80	90	80	90	80	90
1.	Food	0.0535	0.0789	0.1018	0.1005	0.8447	0.8206
2.	Drink (beverages)	0.0774	0.0965	0.3004	0.2341	0.6222	0.6693
3.	Tobacco	0.0191	0.0219	0.5395	0.5669	0.4414	0.4112
4.	Forage	0.0708	0.0406	0.0754	0.0875	0.8538	0.8719
5.	Textiles (except cotton textiles)	0.0892	0.1232	0.2121	0.1187	0.6986	0.7581
6.	Cotton textiles	0.0671	0.1212	0.2274	0.1141	0.7055	0.7647
7.	Clothing	0.1250	0.1351	0.1242	0.1257	0.7508	0.7392
8.	Leather and fur products	0.1294	0.1405	0.1549	0.1086	0.7177	0.7509
9.	Lumber and wood products	0.1858	0.1964	0.1532	0.0703	0.6610	0.7333
10.	Furniture	0.2284	0.1800	0.1422	0.1149	0.6294	0.7051
11.	Papermaking	0.1071	0.1117	0.2329	0.1580	0.6600	0.7303
12.	Painting	0.1588	0.1725	0.1773	0.1463	0.1138	0.6812
13.	Culture, education, sport products	0.1377	0.1836	0.2692	0.1266	0.5931	0.6898
14.	Industrial art products	0.1490	0.1692	0.2542	0.1512	0.5968	0.6796
15.	Supply of electricity, steam, hotwater	0.0590	0.0987	0.6089	0.3619	0.3321	0.5394
16.	Petroleum products	0.0227	0.0468	0.4091	0.2453	0.5682	0.7079
17.	Coke, coal products	0.0949	0.1442	0.1183	0.0437	0.7867	0.8121
18.	Chemical products (except 19)	0.1010	0.0997	0.1540	0.2051	0.6450	0.6954

Table 1 (Continued)

19.	Chemical products for daily use	0.0703	0.0764	0.2890	0.2105	0.6933	0.7131
20.	Medication	0.0725	0.0879	0.2635	0.1970	0.6640	0.7150
21.	Chemical fibres	0.0656	0.0625	0.3456	0.2628	0.5888	0.6747
22.	Rubber products	0.0704	0.1016	0.3123	0.1866	0.6173	0.7118
23.	Plastic products	0.1174	0.1107	0.1843	0.1590	0.6983	0.7303
24.	Construction materials	0.2209	0.2152	0.2304	0.1396	0.5487	0.6452
25.	Ferrous metallurgicals	0.0975	0.1043	0.2441	0.1718	0.6584	0.7238
26.	Non-ferrous metallurgicals	0.0677	0.0750	0.1751	0.1442	0.7572	0.7808
27.	Metal products	0.1820	0.1574	0.1933	0.1339	0.6246	0.7087
28.	Metal products for daily use	0.1725	0.1416	0.1930	0.1661	0.6345	0.6923
29.	Machinery (except for daily use)	0.1974	0.1942	0.2037	0.1372	0.5989	0.6687
30.	Machinery for daily use	0.1269	0.1544	0.3644	0.1176	0.5067	0.7280
31.	Transportation equipment	0.1585	0.1576	0.1979	0.1369	0.6536	0.7055
32.	Electric machinery (except 33)	0.1153	0.1324	0.2492	0.1718	0.6355	0.6958
33.	Home electrical appliances	0.1495	0.0699	0.2392	0.1735	0.6113	0.7566
34.	Electronics and communication	0.1804	0.1325	0.2628	0.1958	0.5568	0.6716
35.	Home electronic appliances	0.1001	0.0565	0.1245	0.1459	0.7755	0.7976
36.	Instruments	0.1747	0.2366	0.3070	0.1670	0.5183	0.5964
37.	Others	0.1857	0.1539	0.1707	0.1253	0.6426	0.7207
All manufacturing total		0.1072	0.1262	0.2467	0.1679	0.6461	0.7060

I. Methodology

In order to investigate quantitatively output growth and productivity change between the whole manufacturing sector and its subsectors, we first construct a two-tier production model: a production function of the manufacturing sector at one level and production functions of subsectors at another level. We express the output of each sector as a function of intermediate input (materials), capital input, labour input, and time.

$$Z_i = F_i(X_i, K_i, L_i, T) \qquad (i = 1, 2, ..., n) \tag{1}$$

where Z_i is output in subsector i; X_i, K_i and L_i are intermediate input, capital input, and labour input in subsector i respectively; T is time. Under the assumptions of producer equilibrium and constant returns to scale, the output elasticities of intermediate input, capital input, and labour input are equal to their respective shares of compensation in output value respectively:

$$\alpha^i_x = \frac{\partial LnZ_i}{\partial LnX_i} = \frac{P^i_x X_i}{q_i Z_i}$$

$$\alpha^i_k = \frac{\partial LnZ_i}{\partial LnK_i} = \frac{P^i_k K_i}{q_i Z_i}$$

$$\alpha^i_l = \frac{\partial LnZ_i}{\partial LnL_i} = \frac{P^i_l L_i}{q_i Z_i}$$

where $q_i Z_i = P^i_x X_i + P^i_k K_i + P^i_l L_i$, and q_i, P^i_x, P^i_k, P^i_l are output price, prices of intermediate input, capital input, and labour input respectively. The growth rate of productivity in each subsector is defined as the rate of change of output with respect to time when X, K and L are kept constant:

$$A^i(T) = \frac{\partial LnZ_i}{\partial T}.$$

In the definition, there is no limitation to the form of input substitution. Comparing period T with T–1, we may compute the average grow rate of productivity using the following expression:

$$\overline{A^i}(T) = LnZ_i(T) - LnZ_i(T-1) - \overline{\alpha^i_x}[LnX_i(T) - LnX_i(T-1)]$$
$$- \overline{\alpha^i_k}[LnK_i(T) - LnK_i(T-1)] - \overline{\alpha^i_L}[LnL_i(T) - LnL_i(T-1)] \tag{2}$$

where

$$\overline{\alpha^i_x} = \frac{1}{2}[\alpha^i_x(T) + \alpha^i_x(T-1)]$$

$$\overline{\alpha^i_k} = \frac{1}{2}[\alpha^i_k(T) + \alpha^i_k(T-1)]$$

$$\overline{\alpha^i_L} = \frac{1}{2}[\alpha^i_L(T) + \alpha^i_L(T-1)]$$

$$\overline{A^i}(T) = \frac{1}{2}[A^i(T) + A^i(T-1)].$$

We assume that the aggregate production function of the manufacturing sector has the same form as its subsectors, i.e.,

$$Z = F(X, K, L, T).$$

Under the same assumption of producer equilibrium and constant returns to scale, the relationship between output growth and growth of inputs from T–1 to T can be expressed as follows:

$$LnZ(T) - LnZ(T-1) = \overline{A}(T) + \overline{\alpha}_x[LnX(T) - LnX(T-1)]$$
$$- \overline{\alpha}_k[LnK(T) - LnK(T-1)]$$
$$- \overline{\alpha}_L[LnL(T) - LnL(T-1)] \tag{3}$$

where the definitions of output elasticities of input and growth rate of productivity are the same for the subsectors. The variables in the aggregate and subsector production functions have the following relationships:

$$K = \sum K_i, \; L = \sum L_i, \; X = \sum X_i, \; Z = \sum Z_i.$$

From Equations (2) and (3), we may derive the quantitative relations among growth, the changes in productivity and the industrial structure with respect to manufacturing and its subsectors. We multiply the two sides of Equation (2) by $W_i = Z_i/\Sigma Z_i$, the share of subsector i in total manufacturing; then summing over all subsectors, and subtracting from Equation (3), the resulting equation is:

$$\begin{aligned}\bar{A}(T) = &\sum W_i \bar{A}^i T \\ &+ \{[LnZ(T) - LnZ(T-1)] - \sum W_i[Z_i(T) - Z_i(T-1)]\} \\ &+ \{\sum W_i \bar{\alpha}_x^i [LnX_i(T) - LnX_i(T-1)] - \bar{\alpha}_x[LnX(T) - LnX(T-1)]\} \\ &+ \{\sum W_i \bar{\alpha}_k^i [LnK_i(T) - LnK_i(T-1)] - \bar{\alpha}_k[LnK(T) - LnK(T-1)]\} \\ &+ \{\sum W_i \bar{\alpha}_L^i [LnL_i(T) - LnL_i(T-1)] - \bar{\alpha}_L[LnL(T) - LnL(T-1)]\}. \qquad (4)\end{aligned}$$

We will analyse the sources of growth in the manufacturing sector by Equation (3), and the sources of productivity changes by Equation (4). In Equation (3), the growth of the manufacturing sector is divided into four parts, i.e., rise in productivity, growth in labour, capital and intermediate input. In Equation (4), the growth of productivity in the manufacturing sector is divided into five parts, i.e., the weighted sum of productivity growth in all subsectors, the effect of changes in output structure, the effect of reallocation of intermediate input, capital input, and labour input among subsectors.

We do not assume that

$$F(X, K, L, T) = \sum F^i(X_i, K_i, L_i, T).$$

This information requires such aggregation property as the Gorman condition.[1] In fact, the aggregate production function is not likely to be the simple sum of subsector production functions. Intersectoral effects, which are exactly what we will analyse, cannot be ignored.

Output elasticities are estimated by the income-share method. Some have questioned whether the method can be applied to the Chinese context. However, we think that the errors associated with this method may not be much larger than those of other methods. An equilibrium condition of some form has to be postulated anyway. Other than the constant returns to scale, the income-share method does not require more assumptions. Any method has its own problems when economic growth fluctuates

significantly, and there are no data on the utilization rate and on the extent of price distortions. The parameters estimated by the regression method can hardly reflect the true relation between output and its inputs. When estimating the frontier production function using micro data, there exists a problem pertaining to the variation in the nature of production and the technological level across micro units. In any case, the results are only approximations. In the economic reform in China, labour income has increasingly been linked to the economic performance of the enterprises. The relationship between labour cost and output has changed fundamentally; more than ever before, wage has been determined by market forces. At present, the distortion of labour price lies mainly in income egalitarianism between the material and non-material production departments, and among the labour force in various sectors and enterprises. To some extent, income differentials among sectors reflect the dispersion of labour output elasticities in these sectors. Although the price system is distorted and incomplete, it has been used for accounting purposes and as the standard for the value of goods and services. The price system (though distorted) determines objectively the behaviour of the people as well as the substitution relationship between capital and labour. In fact, empirical studies show that many sectors' output elasticities tend to be negative when they are more disaggregated. This phenomenon does not show up in estimates derived by the income-share method.

We should point out that the practical experience in computing productivity shows that the results are very much affected by the selection of price indexes for deflating the time series of input and output data. The results are not very sensitive to estimates of output elasticities; this is particularly true for the trends of the results. The discussion of what method to adopt only solve the problems with respect to coefficient estimation. If there is no adjustment or correction of the defective data, the results will not be reliable, regardless of the method.

II. Data and Estimates of Coefficients

Our model assumes a production function with three inputs. We focus on the whole manufacturing sector. The period analysed is from 1980 to 1990. Since 1985, China has adopted a new industrial classification which is consistent with the international standard. As a result, we can compile a complete data set for the manufacturing sector after 1985. Since the classification adopted before 1985 is rather crude, it is difficult to reclassify data from the old system according to the new standard, at least according to the data available. The manufacturing sector is divided into 37 sub-sectors. It is impossible to adjust data before 1985. Data from the 1985 industrial survey are used. In this survey, many variables have 1980 and 1984 data according to the new classification. Thus we have data for 1980, 1984, 1985-1990.

To render our analysis more accurate, we make some necessary adjustments to the existing data:

Gross output: Gross output value is in 1980 constant prices.

Capital input: Adjusted productive gross fixed capital stock is used. Since we focus on growth and productivity, only the part of factor input which is related to production is incorporated. Because the intermediate input is a separate production factor here, capital input should not include working capital. Why do we use gross capital stock? In order to compute change in productivity, we need a quantitative index of fixed capital stock. According to the definition of the production model, capital input is the flow of service from capital used in the production process. Assuming that the flow of service is proportional to capital stock, we use capital stock as a proxy for capital input. The amount of capital input should reflect its instantaneous production capacity; as a proxy, capital stock also should have the same property. Since fixed assets often exhibit constant efficiency or production capacity over the lifetime of the capital goods — and so the quantitative measure of capital stock with this characteristic corresponds to the gross capital stock — thus gross capital stock approximates capital

input more closely than using net capital stock according to the requirement of the neoclassical growth theory.

However, data of gross fixed assets are their book values. We use the following equation to compute the value of gross capital stock at 1980 constant prices:

$$DKFOP_i(T) = KFOP_i(1980) - \sum [KFOP_i(T) - KFOP_i(T-1)]/P_{ki}(T)$$

$$(T = 1981, ..., 1990; i = 1, 2, ..., 37),$$

where $DKFOP_i(T)$ represents the value of gross capital stock at 1980 constant prices in sector i at year T, $KFOP_i(T)$ represents the book value of gross capital stock in sector i at year T, $P_{k,i}(T)$ represents the price index of the newly added capital stock in sector i at year T (the value for 1980 is 1). The price of capital goods was quite stable before 1980, so only the data for newly added capital stock after 1980 are deflated. The capital stocks of different sectors have different compositions of capital goods, and the price movements of different capital goods are not the same, therefore different sectors have different price indexes for newly added capital stocks. We construct capital deflators sector by sector. In this way, we may avoid the distortions induced by using a unique deflator for all sectors.

Labour input: We use the number of productive employees. The average number of employees is the only variable available. We assume that the share of productive employees in the total number of employees is the same as the share of productive gross capital stock in total gross capital stock, and compute the number of productive employees using the share of the latter. Labour input does not take into account changes in the quality of labour. Similar to our treatment of capital, the change in the quality of labour is reflected in the change in overall productivity.

Intermediate input: Data on intermediate input are not available. The following equation is used to compute intermediate input at 1980 constant prices,

$$X_i(T) = [GV_i(T) - NV_i(T) - DEP_i(T)]/P_{x,i}(T)$$

where GV_i, NV_i and DEP_i represent gross value of output, net value of output, and depreciation value at current price in sector i respectively. $P_{x,i}$ represents price index in sector i, X_i represents intermediate input of the ith sector at 1980 constant prices. $P_{x,i}$ is derived using price indexes of sectoral output and the input-output table. Since 1985, the urban household survey conducted by the State Statistical Bureau (SSB) has been publishing price indexes of raw materials, fuel and power each year. Though our price index of intermediate input constructed is lower than that published by SSB, we believe it is more reliable. The price index published by SSB is derived from sample surveys. The sample is not large enough, and there is a tendency for enterprises to exaggerate their costs. In addition, our indexes are consistent with the price indexes of gross output value, thereby minimizing the computational error.

As mentioned above, the income-share method is adopted to estimate output elasticities of inputs. Data on capital compensation are more difficult to find than that on labour compensation. Postulating constant returns of scale, the share of labour compensation is first estimated; shares of value of the intermediate input and labour compensation are then subtracted from 1 to arrive at the share of capital compensation. Hence, the main task is to estimate the labour compensation.

Data on the "sum of wage and salary" are the only figures available. According to the regulation of SSB, the sum of wage and salary includes all incomes that an employee receives directly, e.g., basic wage and salary, various bonuses and subsidies. However, the sum of wage and salary is not the total labour income. In China, two major adjustments have to be made, i.e., adding the welfare fund retained by the enterprise and bonus and welfare funds from retained profit to the sum of wage and salary. An amount equal to a given percentage of the total wage and salary is set aside as the enterprise welfare fund to pay for health care services and collective welfare programmes. Figures on the total wage and salary by sectors are available; data on sectoral welfare funds do not exist on a yearly basis. The only figures on the

sectoral welfare fund are those from the 1985 industrial survey. Assuming that the ratio of the welfare fund to total wage and salary remains constant over the years, the 1985 ratio is used to estimate the welfare fund of each sector in other years. The bonus and welfare funds from retained profit are not included into the labour cost. Only state-owned enterprises (SOE) compile statistics on these special funds. The ratio of the value of these funds to retained profit for the SOEs is used in estimating these funds for all enterprises.

The output elasticities of labour, capital and intermediate input of 1980 and 1990 from the method of income share are reported in Table 1.

As a result of the economic reforms, enterprises have been granted more and more autonomy, and the degree of marketization has increased constantly. The economic environment of China is getting closer to those conditions prevailing in a market equilibrium, at least at the margin. In Table 1, the results are reasonable. The output elasticity of labour goes up and output elasticity of capital goes down over time, consistent with the previous results based on time series data of state-owned enterprises using the translog production function (Chen et al. 1988a).

III. Growth of the Manufacturing Sector and the Sources of Growth in the 1980s

Growth and Change in Structure

The years 1984 and 1988 are the two years in 1980s critical to the economic development of China. In 1984, urban economic reforms were introduced on all fronts, and the dual pricing system was put into operation, invigorating the national economy. In 1988, the government implemented contractionary economic policies, and the national economy sharply declined. The average growth rate of the Chinese manufacturing sector was 11.11 per cent for the whole of the 1980s, 9.83 per cent for 1980-1984, 15.03 per cent for 1984-1988 and 6.09 per cent for 1988-1990.

Table 2 Sources of growth in subsectors of manufacturing, 1980-1990

	Average annual rate of productivity growth (%)	Average annual rate of output growth (%)	Contribution to output growth (output growth = 100)			
			Intermediate input	Capital input	Labour input	Productivity
1. Food	2.46	7.88	47.12	16.59	4.23	32.06
2. Drink (beverages)	-0.89	12.99	59.89	41.12	6.48	-7.48
3. Tobacco	-3.66	12.64	31.97	97.99	1.38	-31.34
4. Forage	2.66	42.40	82.18	7.94	3.55	6.33
5. Textiles (except cotton textiles)	0.46	12.80	67.23	22.11	6.85	3.80
6. Cotton textiles	0.22	6.88	57.19	31.54	7.95	3.32
7. Clothing	1.56	12.17	63.68	17.39	5.41	13.53
8. Leather and fur products	2.67	11.60	54.20	15.43	6.31	24.06
9. Lumber and wood products	1.32	9.14	60.13	13.57	11.30	15.00
10. Furniture	4.31	11.58	49.82	10.88	0.84	38.47
11. Papermaking	1.57	11.16	60.89	19.01	5.41	14.68
12. Painting	2.10	11.22	59.27	16.11	4.12	19.50
13. Culture, education, sport products	1.27	13.06	61.58	20.42	7.74	10.26
14. Industrial art products	1.40	16.08	60.06	22.97	7.67	9.30
15. Supply of electricity, steam, hotwater	-2.11	7.59	67.45	55.92	5.57	-29.14
16. Petroleum products	-1.93	6.77	71.74	54.94	3.10	-29.78
17. Coke, coal products	-2.10	8.91	100.22	12.83	11.85	-24.89

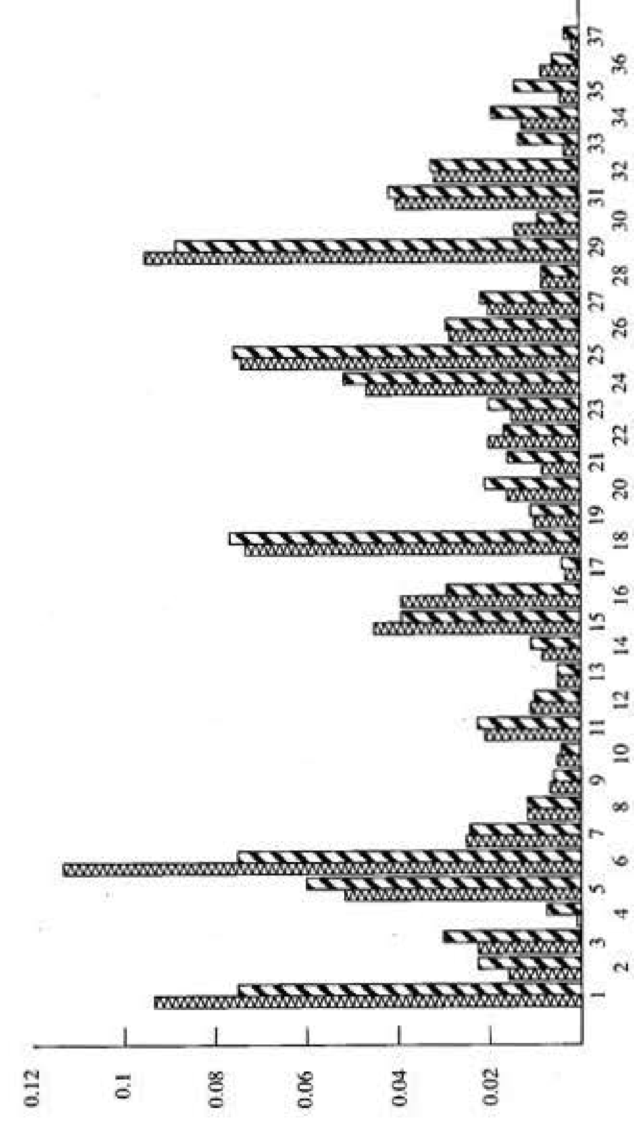
Table 2 (Continued)

18. Chemical products (except 19)	0.85	9.90	69.07	18.01	3.98	8.93
19. Chemical products for daily use	1.08	11.77	61.89	26.34	2.13	9.64
20. Medication	4.52	17.05	51.36	17.51	3.07	28.06
21. Chemical fibres	4.12	22.08	53.64	23.21	2.89	20.26
22. Rubber products	1.19	9.60	56.82	26.14	4.16	12.88
23. Plastic products	2.31	15.28	59.10	20.12	4.74	16.08
24. Construction materials	1.53	11.31	59.58	17.67	8.57	14.18
25. Ferrous metallurgicals	-0.64	7.48	82.96	20.46	5.44	-8.86
26. Non-ferrous metallurgicals	-0.18	7.63	83.55	14.25	4.59	-2.39
27. Metal products	2.82	12.75	61.33	12.06	3.46	23.16
28. Metal products for daily use	2.46	12.16	59.21	16.63	2.96	21.21
29. Machinery (except for daily use)	3.78	11.50	55.76	7.56	1.58	34.10
30. Machinery for daily use	1.10	9.43	59.83	24.43	3.57	12.17
31. Transportation equipment	3.72	12.61	59.45	7.50	2.29	30.76
32. Electric machinery (except 33)	1.67	11.60	62.97	17.29	4.64	15.09
33. Home electrical appliances	5.36	31.24	62.57	15.40	2.82	19.20
34. Electronics and communication	6.58	20.03	51.55	10.93	2.63	34.89
35. Home electronic appliances	5.69	27.61	65.60	9.32	2.40	22.48
36. Instruments	3.92	9.61	41.70	13.68	2.65	41.96
37. Others	3.63	18.28	58.66	14.68	5.40	21.27
All manufacturing total	1.93	11.11	59.66	17.58	4.61	18.15

As shown in Table 2, there exist large differences in growth rates between sectors, with five sectors [animal feed (42 per cent), home electrical appliances (31 per cent), home electronic appliances (27 per cent), chemical fibres (22 per cent), and electronics and communications equipment (except home electronic appliances, 20 per cent)] whose growth rates are over 20 per cent. Six sectors having the lowest growth rates of less than 8 per cent are food, petroleum products, cotton textile, ferrous metallurgy, the supply of electricity, non-ferrous metallurgy. The growth rates of the remaining sectors are very close to each other. The differential growth rates lead to a change in the output structure. Figure 1 reports the shares of 37 subsectors in manufacturing in 1980 and 1990. Sectors whose shares experience the largest increases are home electrical appliances, home electronic appliances, textiles (except cotton textile), chemical fibres, tobacco, electronics and communications equipment, and beverages. The sectors whose shares decline the most are petroleum products, machinery (except machinery for daily use), the supply of electricity, machinery for daily use, rubber, cotton textile, and instruments. But these sectors whose shares increase the most are the main growth poles in the 1980s. During the 1980s, the four sectors whose shares grow continuously are: tobacco, animal feed, chemical fibres, and electronics and communications equipments. Only three sectors grow continuously: food, printing and consumer durables (subsectors 30, 33, 35 etc. in Table 2). The shares of the other 30 sectors do not exhibit a discernible trends suggesting that the Chinese economic development in 1980s is not very stable.

Many economists have explored the laws governing the evolution of the industrial structure. What is the relationship between the change in productivity and industrial structure? In the 1980s, growth rates differ significantly across sectors. What are the reasons? Owing to data limitations, it is hard to give a quantitative analysis. But we may give some qualitative explanations based on such forces as technological push and demand pull. Generally speaking, relative rates of growth for some sectors depend simultaneously on technical push and demand pull. The technological

Figure 1 Sector output weight in 1980 and 1990



levels in different sectors are not equal and are related to the characteristics of the products of different sectors. The rise in technological level mainly affects demand in two directions: (a) by creating new consumer goods, and (b) by increasing demand by raising efficiency and lowering cost. Demand also acts independently as a constraint on production in a given sector. It is the interaction of technology and demand that determines the scale and level of production of a product.

Those sectors that grow fast (such as, home electrical and electronic appliances) have easy access to technologies and have huge demand. The technologies of these sectors are all relatively mature in the world market, the cost of technology transfer is thus relatively low. The growth of these sectors is induced by a technical push in the early 1980s, followed by rapid expansion as a result of demand pull. The weakening of demand ushers in a period of slow growth at the end of the 1980s.

The sluggish sectors, such as, electricity, non-ferrous metallurgy and ferrous metallurgy also experience a strong demand pull, but their technologies are capital-intensive and the cost of acquiring advanced technology is higher. In addition, technical progress in these sectors is slow relative to that of the rising industries due to the nature of their products. Technical push is thus comparatively weak. Furthermore, problems associated with the system governing the allocation of investment funds also adversely affect the development of these sectors.

Though no discernible relationship seems to exist between sectoral growth rates and the productivity levels, a close link between sectoral growth rates and the changes in productivity is detectable. From Table 2, the three sectors that have the highest productivity growth rates are electronics and communications equipment (6.6 per cent), home electronic appliances (5.7 per cent), home electrical appliances (5.3 per cent). Their output growth rates are all over 20 per cent. The seven sectors with negative productivity growth are ferrous metallurgy, non-ferrous metallurgy, petroleum products, coke and coal products, electricity, beverages and tobacco. The growth rates of most of these sectors are lower than the average.

The correlation may be due to the high growth rates resulting in the fuller utilization of capacity in the short run, and economies of scale in the long run exerting a favourable impact on productivity.

Table 3 depicts an obvious correlation between output growth and productivity growth, but it seems that there are no economies of scale at the sectoral level. For example, the growth rates of output in the seven subsectors with negative productivity growth rates are all positive and not too low.

Table 3 Joint distribution of productivity and output growth rates for subsectors of manufacturing (number of subsectors), 1980-1990

Average growth rate of productivity (%)	Average growth rate of output (%)								
	6-8	8-10	10-12	12-14	14-16	16-18	18-20	>20	Total
< 0	4	1		2					7
0-1	1	1		1					3
1-2		3	4	2		1			10
2-3	1		2	2	1			1	7
3-4		1	1	1			1		4
4-5			1			1		1	3
5-6								2	2
> 6								1	1
Total	6	6	8	8	1	2	1	5	37

Analysis of Growth Factors

Using Equations (3) and (4), we may attribute the output growth of manufacturing and its subsectors to the growth of productivity, labour, capital and intermediate input. Using Equation (4), we may decompose the productivity growth of manufacturing into the productivity change of subsectors, the change in output structure and the reallocation of input factors.

At the sectoral level, intermediate input is the major source of output growth in all but one sector (see Table 2). After intermediate input, there are 22 subsectors where capital growth has the largest contribution to output growth, and 15 subsectors with productivity growth having the largest contribution. Even though there are more subsectors with capital contributing more than technological change to output growth, yet the overall picture is that technological change is more important than capital as the source of output growth.

For the manufacturing industry as a whole, Table 4 shows that the growth of the intermediate input is the major source of growth during the 1980s, and the contribution due to the reallocation of intermediate input is very small, especially from 1984 to 1988. The contribution of capital input is lower than that of intermediate input but higher than that of productivity and labour from 1980 to 1984. In the same period, productivity's contribution exceeds that of capital; ignoring intermediate input, productivity's contribution to the remaining part (value added) of growth is 53 per cent from 1984 to 1988.

From 1988 to 1990, capital input's contribution to growth goes up, and productivity's contribution to growth goes down sharply. The slump in productivity after 1988 reflects the abnormal growth due to the implementation of the policy of enterprise subcontracting. Here, 60-70 per cent of the productivity increase of the manufacturing industry comes from the increase in the productivity of the sector in the normal years, but only about 10 per cent from 1988 to 1990. The contribution of the subsectors productivity to manufacturing growth is less than 1 per cent, and is less than that of labour input. The slow growth of productivity in manufacturing is largely attributable to the slow productivity growth in the subsectors. The tight government policy leads to equipment being left idle, resulting in unemployment of resources and a policy-induced depression.

Table 4 Growth sources of manufacturing (%)

	1980-84	1984-88	1988-90	1980-90
(1) Average annual growth rate of output	9.80	15.03	6.09	11.11
(2) Average annual growth rate of labour input	5.04	5.11	1.00	4.25
(3) Average annual growth rate of capital input	7.76	10.84	10.30	9.35
(4) Average annual growth rate of intermediate input	8.73	13.11	5.23	9.70
(5) Average annual growth rate of productivity	1.62	3.11	0.51	1.93
Contribution to output growth (output growth = 100)				
(6) Labour input growth	5.85	4.33	2.13	4.16
(7) Capital input growth	18.99	14.80	29.30	17.58
(8) Intermediate input growth	58.04	59.01	59.93	59.66
(9) Productivity growth	17.12	21.86	8.62	18.15
(10) Subsectors productivity growth	11.76	14.19	0.98	11.00
(11) Change in output structure	0.74	5.30	1.19	3.62
(12) Reallocation of labour	-0.29	-0.04	0.39	-0.08
(13) Reallocation of capital	4.85	2.55	5.36	3.52
(14) Reallocation of intermediate input	0.05	-0.14	0.70	0.10

The period 1984-1989 is the period when the productivity of the manufacturing industry experiences the fastest expansion, but its contribution to growth (value added) is only 53 per cent and is low compared with developed countries in the 1960s and 1970s. In most of the OECD (Organization for Economic Co-operation and Development) countries, productivity's contribution to growth (value added) is more than 60 per cent in the 1960s and about 50 per cent after the oil crisis in the 1970s. With China undergoing a period of economic reform, the rise in productivity may be partly explained by the release of potential capacity. The contribution of technical progress to productivity growth would be even smaller if the effect of the release in potential capacity be taken into account.

Table 4 reports the contribution of the reallocation of inputs to growth. The effect of the reallocation of labour and intermediate input is less than 1 per cent. The effect of the reallocation of capital input, though small, cannot be ignored, especially from 1988 to 1990. It is 1.5 times the contribution of labour growth to output growth.

In the 1980s, the average contribution of the change in output structure to growth is about the same as that of the reallocation of capital, but the patterns of change are different. The contribution of the change in output structure increases and then falls; the contribution of the reallocation of capital exhibits the opposite pattern. The change in the output structure is the result of the reallocation of capital; however the change in the output structure comes about with a lag.

In addition, the contribution of change in output structure and reallocation of inputs [i.e., the sum of item (11) to item (14) in Table (4)] may be regarded as a deviation from the assumption that the aggregate production function is the sum of the sectoral production functions. The deviation is 5.36 per cent for 1980-1984, 7.76 per cent for 1984-1988, 7.64 per cent for 1988-1990 and 7.15 per cent for 1980-1990. The subsectors can be further decomposed into more disaggregated sectors. The relationship between production functions of different aggregate levels can be depicted by Equations (3) and (4), i.e., the change in productivity at a more aggregate level can be decomposed into the weighted sum of productivity changes and the sum of input reallocation effect at a less aggregate level. The higher the degree of aggregation, the more the contribution of the change in the output structure and the change in productivity is. The aggregate production function is thus not the simple summation of subsector or enterprise production functions. The interaction among sectors or enterprises cannot be ignored. We may also think of the deviation as the efficiency gain from reallocation of resources.

IV. Conclusion

There is a rapid expansion of the manufacturing industry in the 1980s. Intermediate input is the factor with the largest contribution followed by productivity, capital and labour. The rise in the productivity accelerates before 1988 implying that the reform is effective.

However, the reform-induced release of the productive potential largely explains the increase in productivity implying that technical progress is slow compared with developed countries. China should thus develop formal mechanisms to promote technological change.

The output structure experiences significant transformation in the 1980s. Though the change in and reallocation of input factors do not have an important effect on growth in the manufacturing industry, the effects of the change in the output structure and the reallocation of capital should not be overlooked.

There is a large dispersion of productivity levels and growth rates among the subsectors. No trend of convergence is discernible because of the nature of their production processes. We cannot explain the dispersion by resorting to supply-side factor alone. However, it is obvious that growth promotes productivity increase, which in turn has a discernible effect on growth.

The sluggishness of the basic industries suggests that the state should allocate more resources to promote productivity growth through technical progress in order to rectify the backwardness of these industries.

Note

1. According to the Gorman condition, the aggregation of subsector production requires that the expansion paths of all subsectors or firms are parallel lines through their origins.

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8

Efficiency Loss from Resource Misallocation in Shanghai's Industry

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I. Introduction

The aim of this chapter is to measure the efficiency loss resulting from misallocation of resources, as revealed by the inequality of the marginal rate of substitution (MRS) among factors in the eight branches of Shanghai industry. In general, the observed situation can be characterized by the absence of equality between the MRS of factors in Shanghai's industrial branches. Hence the reallocation of factors so as to make the MRS equal for each industrial branch will have less factor use for the same output. In other word, the factor saving which could be obtained in producing a given output is to be identified as an efficiency loss. This measure of efficiency captures the degree to which each industrial branch deviates from a given overall average. To check whether the deviation is due to industry-specific reasons, alternative optimal capital and labour will also be calculated.

Economic reforms initiated in 1978 have resulted in decentralization of resource allocation. A rigid central planning has been replaced by enterprise autonomy. The trend has been to rely more on the market mechanism to allocate both inputs and outputs. It is of interest, therefore, to evaluate the performance of Shanghai's industry resulting from these reform measures.

The chapter is divided into four sections. First, the brief sketch of Shanghai's industry is presented in Section II. In Section III, the methodology of analysis is explained. Section IV discusses the statistical data used in the study. Section V presents the efficiency loss calculated. The final concluding section (VI) gives the policy implications and the limitations of our study and suggests future research.

II. Shanghai's Industry

The Position of Shanghai's Industry in China

Shanghai has been China's biggest industrial centre. It reached the peak of its share of industrial output in the nation in 1980. By then the value of industrial output in Shanghai was 11.6 per cent of the national total. Shanghai's export of industrial products was taking up 23.3 per cent of the national total, and its sales profit was as high as 32.9 per cent, ranking the best in China.[1] In the 1930s and 1940s, Shanghai had been the financial and trading centre in East Asia. Since 1949, due to the large volume of energy and raw materials supplied through the central government planning, Shanghai has continued its industrial development, encompassing a comprehensive industrial structure with textile, metallurgy, machinery and chemical industries forming the four pillars.

Technological Progress in Shanghai's Industry

Before 1980, Shanghai was not only the biggest industrial centre in China but it was also taking the lead in the nation's technological progress. According to the estimation (done by the Economic Research Institute of the State Planning Commission and Beijing Machinery Research Institute) on the rate of technological contribution of each province and municipality from 1964 to 1982, Shanghai had a rate of 34.8 per cent, which was much higher than the national average of 20.1 per cent.[2] Fudan University in Shanghai did a similar calculation, and their estimation of Shanghai's rate of technological contribution from 1952 to 1982 was 39.1 per cent.[3] Compared with the developed countries and newly industrialized countries, this rate of progress was not high, but it was still the highest in China.

Change of Status in the 1980s

Since the 1980s, Shanghai's relative position in China has changed dramatically. On the one hand, the general reform has greatly facilitated the economic development in all parts of China, especially in areas such as Guangdong, Jiangsu, Shandong and other provinces and cities on China's southeast coast, where industry has rapidly developed; on the other, due to the deep-rooted management tradition of the centrally planned economy, Shanghai's industrial growth has slowed down. It has no longer enjoyed its leading position. The value of Shanghai's industrial output has decreased from 11.6 per cent of the national total in 1980 to 6.8 per cent in 1990; industrial exports have fallen from 23.3 per cent of the national total to 8.6 per cent;[4] and the rate of technical progress has also fallen from 34.8-39.1 per cent to 19.5 per cent.[5] Moreover, with the large increase in the prices of energy and raw materials supplied by other provinces and cities, Shanghai's industrial cost has risen dramatically, and its sales profits have fallen from 32.9 per cent to 14 per cent.[6] Such drastic changes have attracted much attention from all spheres.

Faced with such dramatic decrease, the central and municipal governments as well as the private and collective enterprises have started to increase investment. From 1949 to 1980, Shanghai's total investment in industry was only RMB 26.017 billion. But from 1981 to 1985, it reached a total of RMB 27.581 billion; and in the period of 1986-1990, it totalled RMB 50.744 billion.[7] Investment in the last 10 years has been over three times than that of the previous 30 years.

Before 1980, Shanghai generated large volumes of industrial output with a relatively small amount of inputs, showing high efficiency. Now with rapidly increasing investment, efficiency may not have necessarily improved. The purpose of this chapter is to look at the investment in Shanghai during the period of 1981 to 1990, analyse the allocation efficiency among different industrial sectors, and search for policies for improving Shanghai's industrial efficiency.

III. Methodology of Analysis

Inefficiency in resource allocation can be viewed from the standpoint of the proportion of factors that can be saved in relation to the optimal use of factors. In Desai and Martin (1983a, 1983b), the theoretical underpinnings of the methodology they use for the analysis of the Soviet industry are explained. In essence, it is the discrepancy in the MRS (thus the implicit wage-rental ratio) among different branches which results in the sub-optimal utilization of inputs. The reallocation of resources, therefore, would enable the economy to produce the same amount of output with less inputs. What is needed is to find a hypothetical wage-rental ratio which, if applied by each branch, would minimize the factor use.

The estimation procedures are stated below:

1. The Cobb-Douglas (CD) production function is estimated for each branch:

$$\ln(\frac{Y_i}{L_i}) = \ln c_i + \lambda_i t + \alpha_i(\frac{K_i}{L_i}) + \varepsilon_i \tag{1}$$

where Y, K, and L are output, capital stock, and labour respectively,[8] ε is the error term. The subscript i refers to the ith industrial branch. The parameters are represented by c_i, λ_i and α_i.

2. We calculate the marginal rate of substitution between capital and labour, which is assumed to be the implied wage-rental ratio for that branch in a given year.

$$w_i = (1-\alpha_i)/\alpha_i\,(K_i/L_i). \tag{2}$$

If, for each i, w_i is identical, then it means the efficiency of factor allocation is achieved. Under this condition, the sum of actual K and L is equal to the sum of efficient capital and labour, denoted by K* and L*. Thus,

$$\frac{\sum K*_i}{\sum L*_i} = \frac{\sum K_i}{\sum L_i}. \tag{3}$$

We shall follow the assumption made by Desai and Martin that this condition holds even if w_i's are not identical, but we try to find the optimal w* which will make the use of both factors reduced by the same proportion. The efficiency loss, μ, therefore, can be expressed in the following forms:

$$\mu = \frac{\sum K_i - \sum K*_i}{\sum K*_i} = \frac{\sum L_i - \sum L*_i}{\sum L*_i}$$

$$= \frac{\sum K_i}{\sum K*_i} - 1 = \frac{\sum L_i}{\sum L*_i} - 1. \tag{4}$$

3. Among all the arbitrary factor-price ratios that can be used to calculate factor saving, one can try out initially with:

$$w* = \frac{1}{N}\sum w_i \qquad (N=8) \tag{5}$$

and calculate the optimal capital-output ratio, k*, and the amounts of efficient capital and labour, K* and L*, for each branch according to the following expressions:

$$K*_i = \frac{\alpha_i}{1-\alpha_i} W* \tag{6}$$

$$L*_i = \frac{Y_i}{c_i} e^{-\lambda_i t} (K*_i)^{-\alpha_i} \tag{7}$$

$$K*_i = K*_i\, L*_i. \tag{8}$$

The iteration continues until the condition, as shown in (3), of the equality between the ratios of total capital and labour for actual and efficient utilization is nearly satisfied.

4. In the process of iteration, the following alternative can be tried:

$$w^{**} = w^* \left(\frac{\sum K_i}{\sum L_i}\right) \text{ divided by } \left(\frac{\sum K_i^*}{\sum L_i^*}\right). \tag{9}$$

We repeat the process as expressed above.

The efficiency loss estimated by the above method provides the overall measure of the amounts of capital and labour that can be saved if all industrial branches confront the identical factor-price ratio. In order to evaluate an industry-specific optimal usage of capital and labour, the following procedures can be used. Let a social utility function be of Stone-Geary type, i.e., $U = \Sigma \gamma_i \ln Y_i$, where γ_i is the "share" parameter. The maximization of U with respect to input allocation subject to Cobb-Douglas production functions, is then,

$$MaxZ = \sum \gamma_i (\ln c_i + \alpha_{i\ln} K_i + (1-\alpha_i)\ln L_i) + u(K - \sum K_i) + v(L - \sum L_i) \tag{10}$$

where u and v are Lagrange multipliers and K and L stand for total capital and labour. The conditions for maximization are:

$$\frac{\alpha_i \gamma_i}{K_i} - u = 0 \tag{11}$$

$$\frac{(1-\alpha_i)\gamma_i}{L_i} - v = 0 \tag{12}$$

$$K - \sum K_i = 0 \tag{13}$$

$$L - \sum L_i = 0 \tag{14}$$

$$K^*_i = \frac{\gamma_i \alpha_i}{\sum \gamma_i \alpha_i} K \tag{15}$$

$$L^*_i = \frac{\gamma_i (1-\alpha_i)}{\sum \gamma_i (1-\alpha_i)} L. \tag{16}$$

A special case for the optimal allocation of factors is that the share parameter is equal to the output share obtained from a linear

system, i.e., $\gamma_i = Y_i/\Sigma Y_i$, analogous to the linear expenditure system. Then,

$$K^* = \frac{\alpha_i Y_i}{\sum \alpha_i Y_i} K \tag{17}$$

$$L^* = \frac{(1-\alpha_i) Y_i}{\sum (1-\alpha_i) Y_i} L. \tag{18}$$

IV. Statistical Data

Two sets of data are used for the estimation of the CD production function for each of the eight branches of Shanghai industry. The first is in current prices and the other is in deflated prices.[9] The former is calculated for reference and for comparison with the latter. The time-series data covering eleven years from 1980 to 1990 are used as sample points. The eight branches are machine building, textile, chemical, metallurgical, food, paper and stationery, construction materials, and forestry industries. Other branches such as petroleum, power, and coal are not included because of the rigidity of their output per labour and capital per labour ratios. In addition, these branches are of the energy sector, in which product prices are strictly controlled by the government and investments have increased very fast.

For these two sets of data, labour is based on mid-year numbers of workers in both cases. Output refers to the value-added of each branch based on the current prices in the first set and on the deflated prices in the second set; the latter are deflated by the price index with 1980 as the base year. In the case of capital, the following adjustments are made:

1. For both sets of data, a portion of fixed assets used for non-productive purposes (such as nursery school, cafeteria, dormitory, etc.) is eliminated.
2. For both sets of data, the productive fixed assets of 1980 are used as benchmarks, and we use the following formula to extrapolate the values of fixed assets for the subsequent years.

Let K^I_t be the original value of fixed assets without eliminating the price effect; and

K^{II}_t be the original value of fixed assets with price effect being eliminated

then

$$K^I_t = (1 - d_t)\,K^I_{t-1} + I_t$$

$$K^{II}_t = (1 - d_t)\,K^{II}_{t-1} + I_t * (100/p_t)$$

where

I_t is the investment in period t

d_t is the depreciation rate in period t

p_t is the investment price index using 1980 as the base year.

Therefore, K^{II}_t can be derived from each year's K^I_t, d_t, and p_t with the following formula:

$$K^{II}_t = (1 - d_t)K^{II}_{t-1} + [K^I_t - (1 - d_t)K^I_{t-1}]*(100/p_t); \quad t > 0$$

$$K^{II}_0 = K^I_0$$

d_t and p_t are defined as follows:

(a) d_t is year t's depreciation rate of fixed assets (it also includes funds for overhaul) (equivalent to replacement cycle of fixed assets). Clearly, a shortened cycle of replacement tends to raise d_t. Suppose the fixed assets bought in the 1980-1983 period have a replacement cycle of 25 years; those bought in the 1984-1987 period have a replacement cycle of 20 years; and those bought in 1988-1990 have a replacement cycle of 15 years, then d_t values for these three periods are 0.04, 0.05 and 0.0667 respectively.

(b) p_t: the investment goods price index represents the rate of price change each year for industrial materials, fuels, power, etc., in Shanghai's industrial enterprises. The information is taken from the research paper, "The Effect of Price Increase in the Means of Production on Shanghai's Local Industry and its Budget as well as the Possible Remedies," published by the Shanghai Academy of Social Sciences in *Information on Price and Cost*, 1988.

These price data are further adjusted to take into account the fact that in the early 1980s the proportion of Shanghai's production materials supplied by the central government was quite large, and it was only in the late 1980s (beginning in 1985 and becoming more of a reality in 1987) that the proportion of government-supplied production materials gradually shrank. Therefore, the transformation from government-supplied to self-procured materials in Shanghai was a bit behind the nationwide schedule. To capture the structural change in Shanghai's industrial material supply so as to capture the impact of price difference between government price and market price on the calculation of Shanghai's industrial price index, we divide the 11-year period into two sub-periods: the first period is from 1980 to 1986 and the second period is from 1987 to 1990.

V. Results of Estimation

The results of estimation are presented in the following four tables. Table 1 shows the parameters of CD production functions for eight industrial branches. Tables 2 and 3 give the estimation results, using the Desai-Martin method, for data set I and II. Table 4 shows the actual and optimal capital and labour when each industry tries to optimize the factor use. The overall efficiency losses are shown in Tables 2 and 3 for 1980, 1985 and 1990. As discussed in Section III, the Desai-Martin method is based on the hypothesis that all industries follow the same wage-rental ratio; thus, it is the planner's choice for the attainment of the overall efficiency. In contrast, the industry-specific optimization is based on the maximization of an objective function in which each industry is to find its own optimal use of inputs according to its own technological conditions. Thus, results in Table 4 are different from those in Tables 2 and 3.

From these tables we can see that there have been efficiency losses in Shanghai's eight industrial branches. Furthermore, both data sets show a worsening trend in the misallocation. For the first set, it changes from 7.7 to 11 and then to 16.7 per cent, while the second set reveals a more precipitous move, from 3.1 to 8.7 and then to 10.7 per cent.

One cannot determine the precise reasons why Shanghai's industry has been suffering from these efficiency losses. The estimation itself cannot tell whether the misallocation has been due to cost-minimizing Chinese entrepreneurs faced with differential factor price ratios as in a competitive economy, or because planning by direction has led to such an outcome. All we can say is that Shanghai's industrial branches have shown a divergence in the wage-rental ratio in utilizing capital and labour, and this divergence has widened during the reform period.

Table 1 Production function estimations for eight branches of Shanghai industry

Branch	c	α	λ	AR(1)	AR(2)	R^2	D.W.	Form
1. Machinery	-0.21	0.59	0	0.60	-0.37	0.90	2.00	CD2
	(-4.76)	(3.12)		(1.42)	(-0.86)			
	0	0.32	0	1.01	-0.37	0.92	2.65	CD2
		(3.04)		(4.08)	(-1.42)			
2. Textile	-0.30	0.26	0	0.60	0	0.59	1.63	CD1
	(-3.02)	(1.46)		(2.77)				
	-0.01	0.27	-0.01	0.29	-0.59	0.56	2.34	CD2
	(-0.10)	(2.95)	(-1.51)	(0.96)	(-1.78)			
3. Chemical	0.14	0.38	0	0.70	0	0.81	1.52	CD1
	(1.13)	(3.16)		(3.18)				
	0.40	0.17	0	0	0	0.82	2.25	CD0
	(34.63)	(6.50)						
4. Metallurgy	0.07	0.16	0	0	0	0.54	0.56	CD0
	(1.13)	(3.22)						
	0.19	0.15	0	0	0	0.68	0.87	CD0
	(5.11)	(4.33)						

Table 1 (Continued)

Branch	c	α	λ	AR(1)	AR(2)	R^2	D.W.	Form
5. Food	0.48	0.42	0	0.32	0	0.73	1.81	CD1
	(7.51)	(3.08)		(0.81)				
	0.69	0.36	0	0.33	0	0.66	1.84	CD1
	(7.00)	(2.41)		(0.93)				
6. Paper	-0.07	0.34	0	0	0	0.91	2.21	CD0
	(-2.97)	(9.62)						
	0.14	0.35	0	0	0	0.87	1.98	CD0
	(0.99)	(7.91)						
7. Construction	-1.47	0.49	0.12	0	0	0.84	2.43	CD0
	(-3.55)	(1.79)	(2.22)					
	-1.06	0.38	0.14	0	0	0.85	2.44	CD0
	(-2.95)	(1.38)	(3.85)					
8. Forestry	-0.50	0.25	0	0	0	0.60	1.03	CD0
	(-11.21)	(3.69)						
	-0.31	0.27	0	0	0	0.31	0.54	CD0
	(-2.33)	(2.16)						

Notes: For each industrial branch, the first and the third line are parameters using Data Set I and II respectively. Numbers in parentheses are the t-value. CD0, CD1 and CD2 are the CD functions with 0, first and second order auto-regressive error terms (indicated by AR(1) and AR(2)).

Table 2 Actual and efficient capital and labour (data set I)

		1980			1985			1990		
		K, K*	L, L*	K/L, K*/L*	K, K*	L, L*	K/L, K*/L*	K, K*	L, L*	K/L, K*/L*
Machine	A	71.6	120.9	0.59	102.4	142.4	0.72	187.6	148.9	1.26
	E	93.8	82.4	1.14	141.7	89.6	1.58	289.3	80.3	3.60
	A/E	0.76	1.47		0.72	1.59		0.65	1.85	
Textile	A	34.6	61.6	0.56	32.4	72.0	0.45	75.1	80.0	0.94
	E	20.6	73.8	0.28	29.1	74.8	0.39	71.8	81.3	0.88
	A/E	1.68	0.83		1.11	0.96		1.05	0.98	
Chemical	A	16.9	20.6	0.82	55.5	35.2	1.57	97.6	40.4	2.42
	E	12.4	25.0	0.50	33.3	48.4	0.69	74.6	47.6	1.57
	A/E	1.36	0.82		1.67	0.73		1.31	0.85	
Metallurgy	A	20.5	16.6	1.23	50.9	20.5	2.49	178.2	23.0	7.73
	E	3.5	23.2	0.15	6.4	30.4	0.21	17.2	35.9	0.48
	A/E	5.86	0.72		7.95	0.67		10.36	0.64	
Food	A	3.9	8.1	0.48	7.4	10.6	0.70	21.9	12.2	1.80
	E	4.4	7.5	0.59	8.1	10.0	0.81	22.1	12.0	1.84
	A/E	0.89	1.08		0.91	1.06		0.99	1.02	

Table 2 (Continued)

Paper	A	4.8	13.2	0.36	9.1	18.0	0.50	19.2	20.6	0.93
	E	5.3	12.5	0.42	10.0	17.1	0.58	24.3	18.2	1.34
	A/E	0.91	1.06		0.91	1.05		0.79	1.13	
Construction	A	6.0	11.5	0.52	9.9	15.1	0.65	21.7	4.7	4.63
	E	7.3	9.5	0.77	12.8	11.8	1.08	15.7	6.4	2.45
	A/E	0.82	1.21		0.77	1.28		1.38	0.73	
Forest	A	1.4	3.8	0.38	2.1	4.2	0.50	3.8	3.6	1.06
	E	1.1	4.2	0.26	1.7	4.5	0.38	3.2	3.8	0.84
	A/E	1.27	0.90		1.24	0.93		1.19	0.95	
Total	A	159.7	256.3	0.62	269.6	318.1	0.85	604.9	333.3	1.82
	E	148.3	238.0	0.62	242.9	286.6	0.85	518.3	285.5	1.82
	A/E	1.08	1.08		1.11	1.11		1.17	1.17	
Loss	(%)	8	8		11	11		17	17	

Notes: Capital is in 100 million RMB. Labour is in 10 thousand people. A, E and A/E stand for actual, efficient and the ratio between A and E.

Table 3 Actual and efficient capital and labour (data set II)

		1980			1985			1990		
		K, K*	L, L*	K/L, K*/L*	K, K*	L, L*	K/L, K*/L*	K, K*	L, L*	K/L, K*/L*
Machine	A	51.1	120.9	0.42	68.1	142.4	0.48	149.0	148.9	1.00
	E	59.3	112.5	0.52	89.7	124.7	0.72	234.1	121.0	1.93
	A/E	0.86	1.01		0.76	1.14		0.64	1.23	
Textile	A	26.0	61.6	0.42	18.2	72.0	0.25	39.6	80.0	0.50
	E	25.5	62.0	0.41	32.5	57.9	0.56	66.1	65.9	1.00
	A/E	1.02	0.99		0.56	1.24		0.60	1.21	
Chemical	A	11.5	20.6	0.56	44.1	35.2	1.25	58.2	40.4	1.44
	E	5.4	24.1	0.22	13.8	44.8	0.31	26.2	47.6	0.55
	A/E	2.13	0.85		3.20	0.79		2.22	0.85	
Metallurgy	A	15.2	16.6	0.92	39.3	20.5	1.92	109.7	23.0	4.77
	E	4.2	21.0	0.20	7.5	27.7	0.27	15.8	32.7	0.48
	A/E	3.62	0.79		5.24	0.74		6.94	0.70	
Food	A	2.7	8.1	0.33	5.3	10.6	0.50	12.5	12.2	1.02
	E	4.0	6.5	0.62	7.4	8.8	0.84	16.0	10.6	1.51
	A/E	0.68	1.25		0.72	1.20		0.78	1.15	

Table 3 (Continued)

Paper	A	3.2	13.2	0.24	6.4	18.0	0.36	10.9	20.6	0.53
	E	5.7	9.6	0.59	10.9	13.5	0.81	20.9	14.4	1.43
	A/E	0.56	1.38		0.59	1.33		0.52	1.43	
Construction	A	4.7	11.5	0.41	7.2	15.1	0.48	12.4	4.7	2.64
	E	6.4	9.5	0.67	10.8	11.7	0.92	9.2	5.6	1.64
	A/E	0.73	1.21		0.67	1.29		1.35	0.84	
Forest	A	1.0	3.8	0.26	1.4	4.2	0.33	2.04	3.6	0.57
	E	1.4	3.4	0.41	2.0	3.6	0.56	3.04	3.1	0.98
	A/E	0.71	1.12		0.70	1.17		0.67	1.16	
Total	A	115.4	256.3	0.45	189.9	318.1	0.60	346.5	333.3	1.43
	E	111.9	248.6	0.45	174.7	292.6	0.60	312.9	301.0	1.43
	A/E	1.03	1.03		1.09	1.09		1.11	1.11	
Loss	(%)	3	3		9	9		11	11	

Notes: Capital is in 100 million RMB. Labour is in 10 thousand people. A, E and A/E stand for actual, efficient and the ratio between A and E.

Table 4 Industry-specific actual and optimal capital and labour

		1980		1985		1990	
Branch		K	L	K	L	K	L
Machinery	IA	71.6	120.9	102.4	142.4	187.7	148.9
	O	84.8	64.3	151.4	94.1	310.0	84.6
	IIA	51.1	120.9	68.1	142.4	101.2	148.9
	O	49.6	86.7	91.4	121.6	148.6	111.7
Textile	IA	34.6	61.6	32.4	72.0	75.1	80.0
	O	28.1	86.8	27.4	69.3	66.4	73.8
	IIA	26.0	61.6	18.2	72.0	39.6	80.0
	O	31.3	70.2	31.5	53.7	60.6	58.4
Chemical	IA	16.9	20.6	55.5	48.4	97.6	40.4
	O	22.1	38.6	45.8	65.5	106.7	66.9
	IIA	11.5	20.6	44.1	35.2	58.2	40.4
	O	10.5	42.7	22.4	69.5	41.3	72.5
Metallurgy	IA	20.5	16.6	50.9	30.4	178.2	23.0
	O	6.2	35.5	8.7	40.5	25.5	52.2
	IIA	15.2	16.6	39.3	20.5	109.7	23.0
	O	6.3	29.4	9.1	32.2	21.3	42.4
Food	IA	3.9	8.1	7.4	10.0	21.9	12.2
	O	7.8	11.5	14.0	19.2	47.4	25.4
	IIA	2.7	8.1	5.3	10.6	12.5	12.2
	O	7.1	10.4	13.1	14.8	35.4	22.5
Paper	IA	4.8	13.2	9.1	17.1	19.2	20.6
	O	6.2	12.7	11.4	19.2	27.9	20.5
	IIA	3.2	13.2	6.4	18.0	10.9	20.6
	O	6.7	10.4	12.7	15.0	24.6	16.4
Construction	IA	6.0	11.5	9.9	15.1	21.7	4.7
	O	3.6	4.0	9.6	8.8	19.3	7.7
	IIA	4.7	11.5	7.2	15.1	12.4	4.7
	O	2.9	4.0	8.1	8.4	13.0	7.6

Table 4 (Continued)

Forestry	IA	1.4	3.8	2.1	4.2	3.8	3.6
	O	0.9	3.0	1.4	3.7	1.8	2.2
	IIA	1.0	3.8	1.4	4.2	2.0	3.6
	O	1.0	2.4	1.6	2.8	1.7	1.7

Notes: Capital is in 100 million RMB. Labour is in 10 thousand people. IA and IIA stand for actual figures for data set I and II respectively. O stands for optimal.

One can only speculate on the main causes of the efficiency loss in Shanghai's industry. They are:

(a) The investment allocation among various industrial sectors is irrational. From Table 2 and Table 3 we can see that investment was excessive in metallurgical and chemical industries. Table 4 confirms the actual capital investment in metallurgical industry exceeding the optimal level by several times. However, in the chemical industry, the capital-labour ratio may be greater than the average of the 8 branches, its industry-specific factors (as Table 4 shows) suggest otherwise. During the period of 1980 to 1990, the fixed assets of Shanghai's metallurgical industry increased from RMB 2.047 billion to RMB 17.815 billion, which was 7.7 times higher than the 1980 level, while the net output value of that sector only increased from RMB 1.93 billion to RMB 3.99 billion, representing a 110 per cent increase. As a result, the ratio of actual to efficient use of capital was 400-700 per cent higher than the optimal level (using the second data set, Table 3). Clearly the overheated investment in these sectors was not justified and did not yield a satisfactory return.

Before 1980, metallurgical and textile industries had used to form the backbone of Shanghai's industry. The added values of these two industries had not been high at all. The sustained rapid development in these sectors had mainly been due to the cheap energy and material supply guaranteed by the central government. In the 1980s, with the rising of energy and material prices such as those of coal, pig iron and cotton, the metal and textile industries gradually lost their competitive advantage and development potentials.

(b) Similar to the problems in investment, the labour force allocation among different sectors was also out of balance. Under the centrally planned system, labour supply was not allocated based on the demand for labour but was equally assigned to each sector.

(c) The general price increase in energy and raw materials had a tremendous impact on Shanghai's resource allocation. A comparison between Tables 2 and 3 suggests that the price increase intensified the efficiency loss. Due to the price increase, the loss in efficiency in 1990 over 1980 shows a larger increase. It may be that, prior to the economic reform, the price level of material and energy resources was unreasonably low. This greatly benefited Shanghai's industry. After the reform, the prices of energy and raw materials all went up, drastically reducing the profits of Shanghai's industrial products.

VI. Conclusion and Future Research

Before we draw any definitive conclusion, it is important to state the limitations and shortcomings of our estimation methods. The Desai-Martin method is based on the assumptions that productive factors are freely mobile and mutually substitutable. To what extent these assumptions are valid in the Chinese economy requires further testing. In addition, the analysis ignores the possibility that capital and labour are branch-specific rather than homogeneous.

It may also be useful to test the validity of the Desai-Martin method by applying it to U.S. data to show whether it would indeed produce smaller efficient losses due to the presumably more competitive and mobile productive factors in a market economy.

These limitations notwithstanding, it may be true that the evidence of divergence in resource utilization among industrial branches cannot be completely denied.

Notes

1. Data are from *Shanghai's Statistical Yearbook, 1981*.
2. See Research Institute of State Economic Commission, Mechanical Science Research Institute (1984).
3. See School of Management, Fudan University (1984).
4. Date are from *Shanghai's Statistical Yearbook, 1991*.
5. See Shanghai's Statistical Bureau (1991).
6. The same as Note 4.
7. The same as Note 4.
8. Alternatively, the CES or other production functions may be tried. Unfortunately, the choice of functional forms is not free. For example, the translog production function cannot be used because of the complex expression of its MRS. Desai and Martin (1983b) use both CD and CES functions.
9. It can be argued that the production function, so far as it is meant to track the physical and technological frontier, ought to be based on real variables in which price changes are deflated. To the extent that we are interested in the decision of enterprise managers in choosing inputs, a comparison between un-deflated and deflated variables may show the effect of possible money illusion.

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9

Evaluation of Technological Progress by the DEA Method

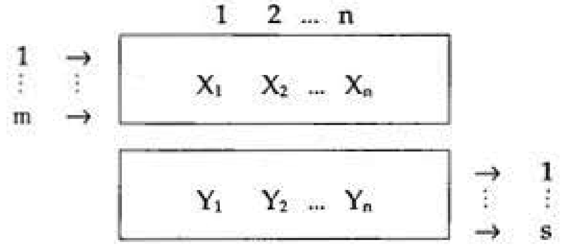
Wei Quanling

The DEA (Data Envelopment Analysis) method initially proposed by Profs. A. Charnes, W. W. Cooper and others in the United States made its first debut in 1978. The DEA method can be regarded as a kind of non-parameter statistical estimation method, the essence of which is the determination of the frontier of production surface. Making use of the changes in the production surface, one can study the state of technological progress from the initial time at l=0 to time l=t. From Wei, Sun and Xiao (1991); Wei, Li and Xiao (1991) and Xiao (1991), we obtain the rate of technological progress for industry and the rate of technological progress as well as the relative performance in technological progress for various enterprises in regard to neutral technological progress and factors-growth-type technological progress.

Based on the foundations of these three papers, this chapter studies the most recent theory on the estimation of technological progress and provides an integral method to estimate the rate of technological progress in the case of multiple factor inputs for industry.

I. DEA Model and Its Method

Suppose that there are n enterprises (called *decision making units*, DMU). They have m factor inputs and s outputs; these data appear as follows:



where

X_j = the input vector of DMU j, j=1, ..., n

Y_j = the output vector of DMU j, j=1, ..., n.

The linear programming (P_1) for the evaluation of DMU j_0 is

$$\max Z$$

$$(P_1)\ s.t. \begin{cases} \sum_{j=1}^{n} X_j \lambda_j \le X_{j0} \\ \sum_{j=1}^{n} Y_j \lambda_j \ge Z Y_{j0} \\ \sum_{j=1}^{n} \lambda_j \le 1, \lambda_j \ge 0, j = 1, 2, ..., n. \end{cases}$$

Definition 1: If (Z^0, λ_j^0, j=1, ..., n) is the optimal solution of (P_1), which satisfies Z^0=1, the DMU j_0 is then called DEA efficient.

Let

T = {(X, Y) | Y be produced by input X}.

We know that

$(X_j, Y_j) \in T$, j=1, 2, ..., n. Assuming that (referring to Fare et al. 1989)

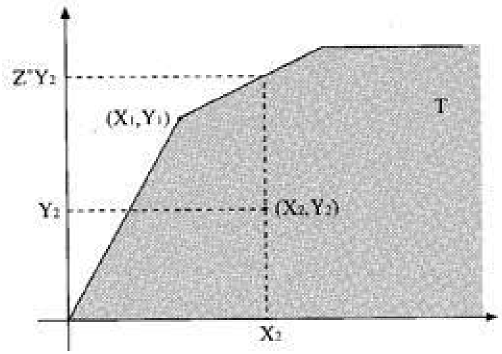
$$T = \left\{(X, Y) \mid \sum_{j=1}^{n} X_j \lambda_j \le X, \sum_{j=1}^{n} Y_j \lambda_j \ge Y, \sum_{j=1}^{n} \lambda_j \le 1, \lambda_j \ge 0, j=1, 2, ..., n\right\}$$

the linear programming (P_1) can be rewritten as

$$\begin{cases} \max Z \\ (X_{j0}, ZY_{j0}) \in T. \end{cases}$$

From Figure 1, the DMU at (X_1, Y_1), is DEA efficient, whereas the DMU at (X_2, Y_2) is regarded as DEA inefficient.

Figure 1



Let

$\hat{X} = X_{j0}$, $\hat{Y} = Z^0 Y_{j0}$,

where Z^0 is the optimal value of (P_1). We call ($\hat{X}$, $\hat{Y}$) the projection of DMU j_0 onto the frontier of production surface. Apparently, ($\hat{X}$, $\hat{Y}$) is DEA efficient.

II. The Neutral Technological Progress

Consider the production function $y_l = A_l f(x)$ in which l is a real number, $x = (x_1, \ldots, x_m)^T$. From time l=t–1 to time l=t, the rate of technological progress is

$$a = \frac{A_l - A_{l-1}}{A_{l-1}} = \frac{A_l}{A_{l-1}} - 1$$

so

$$A_l = A_{l-1}(1+a) = \ldots = A_0(1+a)^l.$$

Thus

$$a = \sqrt[l]{\frac{A_l}{A_0}} - 1. \qquad (1)$$

Let us consider n numbers of DMU at time l=0 and l=t; their input and output data are presented respectively in the following two tables:

$$\begin{array}{cc|ccc|cc} & & 1 & 2 & \ldots\ n & & \\ \hline 1 & \rightarrow & & & & & \\ \vdots & \vdots & X_1^0 & X_2^0 & \ldots\ X_n^0 & & \\ m & \rightarrow & & & & & \\ \hline & & Y_1^0 & Y_2^0 & \ldots\ Y_n^0 & \rightarrow & 1 \\ \hline \end{array}$$

$$\begin{array}{cc|ccc|cc} & & 1 & 2 & \ldots\ n & & \\ \hline 1 & \rightarrow & & & & & \\ \vdots & \vdots & X_1^t & X_2^t & \ldots\ X_n^t & & \\ m & \rightarrow & & & & & \\ \hline & & Y_1^t & Y_2^t & \ldots\ Y_n^t & \rightarrow & 1 \\ \hline \end{array}$$

Estimating the Rate of Technological Progress by Industrial Sectors

The linear programming of (P_2) is to determine the projection onto the frontier of the production surface (k=1, 2, ..., n) for each DMU at time l=0

$$\max Z$$

$$(P_2)\ \ s.t.\ \begin{cases} \sum_{j=1}^{n} X_j^0 \lambda_j \le X_k^0 \\ \sum_{j=1}^{n} Y_j^0 \lambda_j \ge Z Y_k^0 \\ \sum_{j=1}^{n} \lambda_j \le 1,\ \lambda_j \ge 0,\ j = 1, 2, \ldots, n. \end{cases}$$

Suppose the optimal solution of (P_2) is Z^k, λ_j^k, j=1, ..., n. The projection is

$$\hat{X}_k = \sum_{j=1}^{n} X_j^0 \lambda_j^k$$

$$\hat{Y}_k = \sum_{j=1}^{n} Y_j^0 \lambda_j^k$$

Then $(\hat{X}_k, \hat{Y}_k)$ is on the frontier of the production surface.

Consider the linear programming of (P_3) (k=1, 2, ..., n)

$$\max Z$$

$$(P_3)\ \ s.t.\ \begin{cases} \sum_{j=1}^{n} X_j^t \lambda_j + \hat{X}_k \lambda_0 \le \hat{X}_k \\ \sum_{j=1}^{n} Y_j^t \lambda_j + \hat{Y}_k \lambda_0 \ge Z\hat{Y}_k \\ \sum_{j=1}^{n} \lambda_j \le 1,\ \lambda_j \ge 0,\ j=0,1,2,\dots,n. \end{cases}$$

Let the optimal value of (P_3) be Z_k^*, then ($\hat{X}_k$, Z_k^*, $\hat{Y}_k$) is on the frontier of the production surface at time l=t; thus

$$Z_k^* = \frac{Z_k^* \hat{Y}_k}{\hat{Y}_k} = \frac{A_t f(\hat{X}_k)}{A_0 f(\hat{X}_k)} = \frac{A_t}{A_0}.$$

From equation (1)

$$a_k = \sqrt[t]{Z_k^*} - 1,\ k=1,2,\dots,n.$$

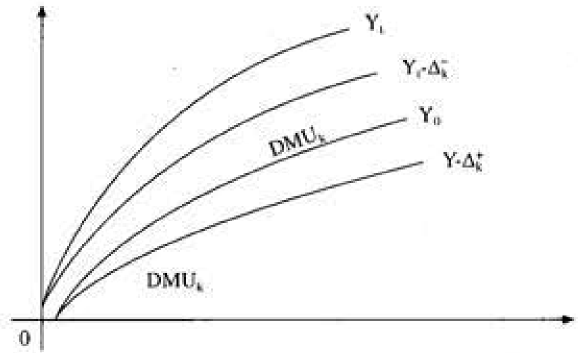
Finally, the rate of technological progress by sectors obtained is

$$a^* = \frac{1}{n}\sum_{k=1}^{n} a_k.$$

Estimating the Relative Performance in Technological Progress for Each DMU

Let (X_k^0, Y_k^0) locate on the frontier of the production surface at time $l = -\Delta_k^+$; (X_k^t, Y_k^t) is on the frontier of the production surface at time $l = t - \Delta_k^-$, where $\Delta_k^+ \ge 0$, $\Delta_k^- \ge 0$ (see Figure 2).

Figure 2



Considering the linear programming of (P_4)

$$\max Z$$

$$(P_4)\ \ s.t.\ \begin{cases} \sum_{j=1}^{n} X_j^t \lambda_j \le X_k^t \\ \sum_{j=1}^{n} Y_j^t \lambda_j \ge Z Y_k^t \\ \sum_{j=1}^{n} \lambda_j \le 1,\ \lambda_j \ge 0,\ j=1,2,\dots,n \end{cases}$$

let Z_k^t be the optimal value for (P_4), then

$$(1+a^*)^{\Delta_k^-} = \frac{A_t}{A_{t-\Delta_k^-}} = Z_k^t$$

so

$$\Delta_k^- = \frac{\log Z_k^t}{\log(1+a^*)}. \qquad (2)$$

Considering further the linear programming of (P_5)

$$\max Z$$

$$(P_5)\ s.t. \begin{cases} \sum_{j=1}^{n} X_j^0 \lambda_j^0 \leq X_k^0 \\ \sum_{j=1}^{n} Y_j^0 \lambda_j^0 \geq Z Y_k^0 \\ \sum_{j=1}^{n} \lambda_j \leq 1, \lambda_j \geq 0, j = 1, 2, \ldots, n \end{cases}$$

let Z_k^0 be the optimal value for (P_5), then

$$(1 + a^*)^{\Delta_k^+} = \frac{A_0}{A_{-\Delta_k^+}} = Z_k^0$$

so

$$\Delta_k^+ = \frac{\log Z_k^0}{\log(1 + a^*)}. \quad (3)$$

Thus, the relative number of years for technological progress of DMU k is

$$t + \Delta_k^+ - \Delta_k^-.$$

There are five situations illustrated as follows:

(1) If $\Delta_k^+ - \Delta_k^- > 0$, then $\Delta_k^+ - \Delta_k^-$ is the number of years the *kth* DMU is relatively more advanced in terms of technological progress;
(2) If $\Delta_k^+ - \Delta_k^- = 0$, then the *kth* DMU is neither relatively more advanced nor is it falling behind;
(3) If $-t < \Delta_k^+ - \Delta_k^- < 0$, then $\Delta_k^+ - \Delta_k^-$ is the number of years the *kth* DMU is lagging behind in terms of technological progress;
(4) If $t + \Delta_k^+ - \Delta_k^- = 0$, then the technological progress of the *kth* DMU is relatively stagnant (i.e., t years lagging behind);

(5) If $t + \Delta_k^+ - \Delta_k^- < 0$, then $\Delta_k^+ - \Delta_k^- - t$ is the number of years of relative retrogression in technological progress of the *kth* DMU.

Estimating the Rate of Technological Progress for Each DMU

Assuming that Δ_k^- and Δ_k^+ are given by Equations (2) and (3), respectively, and a^* is the rate of technological progress of the *kth* DMU in year t, then we have

$$(1 + a_k^*)^t = (1 + a^*)^{t + \Delta_k^+ - \Delta_k^-}$$

so

$$a_k^* = (1 + a^*)^{\frac{t + \Delta_k^+ - \Delta_k^-}{t}} - 1$$
$$= (1 + a^*) \sqrt[t]{\frac{Z_k^0}{Z_k^t}} - 1.$$

III. Integral Approximation Method

In this section, we are going to estimate the factor-expansion-induced technological progress. Different from Wei, Sun and Xiao (1991); Wei, Li and Xiao (1991) and Xiao (1991), the number of factor inputs can be arbitrarily large here. Moreover, it does not require that the production function is homogeneous of the first degree. Assuming that

(a) The production function $f_l(X_1, \ldots, X_m)$ is a continuous concave function which is partially differentiable, l=0, t;

(b) For any $X=(X_1, \ldots, X_m)^T > 0$ and any i(i=1, 2, ..., m),

$$\frac{\partial f_l(x)}{\partial x_i} > 0, l = 0, t.$$

With no loss in generality, let us consider

$$y_0 = f_0(x_1, x_2, \ldots, x_m) = f(A_0 x_1, x_2, \ldots, x_m)$$
$$y_t = f_t(x_1, x_2, \ldots, x_m) = f(A_t x_1, x_2, \ldots, x_m)$$

in which

$$A_t > A_0 > 0$$

then the rate of technological progress is

$$a^* = \sqrt[t]{\frac{A_t}{A_0}} - 1.$$

Now we are going to estimate $Z^*=(A_t/A_0)$. For any $\hat{X}_i > 0$ (i=1, 2, ..., m) since

$$\int_0^{\bar{x}_1}\int_0^{\bar{x}_2}\cdots\int_0^{\bar{x}_m} f(A_t\, x_1, x_2, ..., x_m)\, dx_1, dx_2 \ldots dx_m$$

$$= \frac{A_0}{A_t}\int_0^{\frac{A_t}{A_0}\bar{x}_1}\int_0^{\bar{x}_2}\cdots\int_0^{\bar{x}_m} f(A_0\, x_1, x_2, ..., x_m)\, dx_1, dx_2 \ldots dx_m$$

thus

$$Z^* = \frac{\int_0^{Z^*\bar{x}_1}\int_0^{\bar{x}_2}\cdots\int_0^{\bar{x}_m} f_0(x_1, x_2, ..., x_m)\, dx_1, dx_2 \ldots dx_m}{\int_0^{\bar{x}_1}\int_0^{\bar{x}_2}\cdots\int_0^{\bar{x}_m} f_t(x_1, x_2, ..., x_m)\, dx_1, dx_2 \ldots dx_m}.$$

Let

$$\varphi(Z) = \frac{\int_0^{Z\bar{x}_1}\int_0^{\bar{x}_2}\cdots\int_0^{\bar{x}_m} f_0(x_1, x_2, ..., x_m)\, dx_1, dx_2 \ldots dx_m}{\int_0^{\bar{x}_1}\int_0^{\bar{x}_2}\cdots\int_0^{\bar{x}_m} f_t(x_1, x_2, ..., x_m)\, dx_1, dx_2 \ldots dx_m}$$

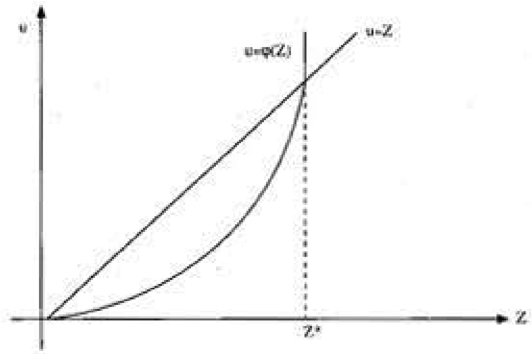
then $\varphi(Z)$ possesses the following properties:

(1) $\varphi(Z)$ is a strictly convex function on $Z \in [o, \infty]$

(2) $Z - \varphi(Z) = \begin{cases} > 0, \text{ if } Z \in (0, Z^*) \\ < 0, \text{ if } Z \in (Z^*, \infty) \end{cases}$

(3) For $Z > 0$, Z^* is the only fixed point for $\varphi(Z)$, i.e., $\varphi(Z^*) = Z^*$ (see Figure 3).

Figure 3

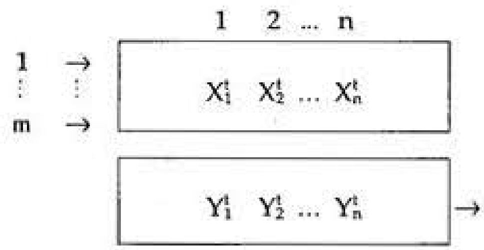


To calculate the fixed point $\varphi(Z)$ at time Z^*, multiple integration is needed. In general, we use the numerical method to approximate the integrals, e.g., the lattice point method:

$$\int_0^{\bar{x}_1}\int_0^{\bar{x}_2}\cdots\int_0^{\bar{x}_m} f_t(x_1, x_2, ..., x_m)\, dx_1, dx_2 \ldots dx_m$$

$$= \left(\prod_{i=1}^{m} \bar{X}_i / K\right) \sum_{l_1, l_2, \ldots, l_m = 1}^{k} f_t(l_1 \cdot \bar{X}_1/k, l_2 \cdot \bar{X}_2/k, ..., l_m \cdot \bar{X}_m/k).$$

However, the value of $f_t(x_1, x_2, ..., x_m)$ is unknown, we can use the DEA method to calculate the value of the function. Taking the corresponding input and output data, the DMU is at l=t as follows:



Solving the linear programming problem of (P_6) (and assuming that $f_t(\hat{X}) \geq 1$)

$$\max Z = \hat{Z}$$

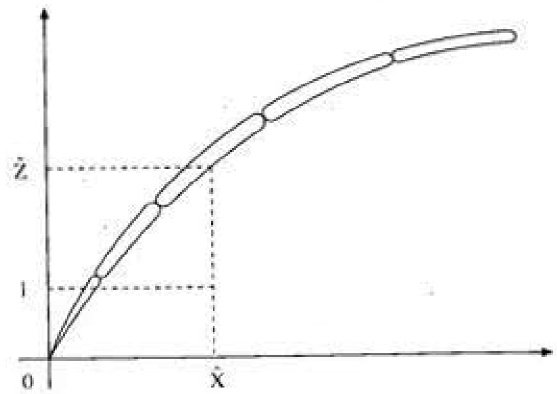
$$(P_6)\ s.t. \begin{cases} \sum_{j=1}^{n} X_j^t \lambda_j + \hat{X} \lambda_0 \leq \hat{X} \\ \sum_{j=1}^{n} Y_j^t \lambda_j + \hat{Y} \lambda_0 \geq Z \cdot 1 \\ \sum_{j=1}^{n} \lambda_j \leq 1, \lambda_j \geq 0, j = 0, 1, 2, \ldots, n \end{cases}$$

we have

$$f_t(\hat{X}) = f_t(\hat{X}_1, \hat{X}_2, \ldots, \hat{X}_m) = \hat{Z}$$

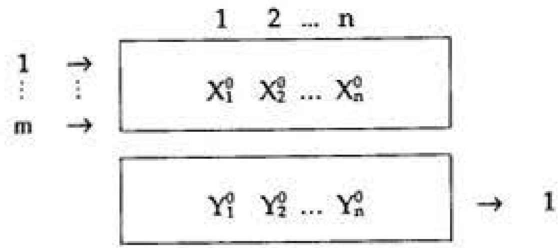
referring to Figure 4.

Figure 4



When we use the data at time l=0, we can apply a similar method to calculate the multiple integrals:

$$\int_0^{\bar{x}1}\int_0^{\bar{x}2}\cdots\int_0^{\bar{x}m} f_0(x_1, x_2, \ldots, x_m)\, dx_1, dx_2 \ldots dx_m$$



Remark: It is very simple to use the integral method to calculate the rate of neutral technological progress. In effect, we obtain

$$Z^* = \frac{A_t}{A_0} = \frac{\int_0^{\bar{x}1}\cdots\int_0^{\bar{x}m} A_t f(x_1, \ldots, x_m)\, dx_1 \ldots dx_m}{\int_0^{\bar{x}1}\cdots\int_0^{\bar{x}m} A_0 f(x_1, \ldots, x_m)\, dx_1 \ldots dx_m}$$

$$= \frac{\int_0^{\bar{x}1}\cdots\int_0^{\bar{x}m} f_t(x_1, \ldots, x_m)\, dx_1 \ldots dx_m}{\int_0^{\bar{x}1}\cdots\int_0^{\bar{x}m} f_0(x_1, \ldots, x_m)\, dx_1 \ldots dx_m}.$$

IV. An Empirical Example

In what follows, an attempt is made to evaluate the state of technological progress of the agricultural sector in 29 provinces, municipalities directly under the Central Government and autonomous regions (PMAR) (excluding Hainan and Taiwan) during the period 1986-1990. The factor inputs for the study are: (1) the total sown area for agricultural products; (2) the labour force (farming, forestry, animal husbandry, side-line production and fishing); (3) the material consumption of the agricultural sector. The production indicator is total output value of the agricultural sector. By using the data of 1986 and of 1990 which are provided by the Ministry of Agriculture, we are able to proceed. According to the actual state of China's agricultural sector, we adopt the neutral technological progress model to conduct an evaluation of the state of technological progress (referring to Section II of this chapter).

In 1986 (l=0), there are 11 PMARs which are DEA efficient; the serial numbers are: 1, 6, 8, 9, 10, 11, 15, 17, 19, 24, 29; in 1990 (l=t=5), there are also 11 PMARs which are DMU efficient; the serial numbers are: 1, 6, 8, 9, 15, 17, 19, 21, 23, 24, 29.

The rate of technological progress in China's agricultural sector, a^*, is 0.026807. The distribution of the relative number of years of technological progress in each PMAR is as follows: eight of them are more advanced; nine in total keep constant; nine of them are lagging behind; one is stagnant; and two are retrogressive. According to the order of the rate of technological progress, the state of each PMAR is presented below:

Serial number of PMAR	Rate of technological progress, a_k^*	No. of years of relative advance and lag, $\Delta_k^+ - \Delta_k^-$
4	0.05326	4.81
5	0.05038	4.29
16	0.03626	1.73
13	0.03283	1.11
21	0.03212	0.98
7	0.03045	0.67
26	0.02942	0.48
23	0.02690	0.01
1	0.02681	0.00
6	0.02681	0.00
8	0.02681	0.00
9	0.02681	0.00
15	0.02681	0.00
17	0.02681	0.00
19	0.02681	0.00
24	0.02681	0.00
29	0.02681	0.00
20	0.02452	-0.42
25	0.02217	-0.86
11	0.01845	-1.54
12	0.01710	-1.80
18	0.01619	-1.96
27	0.01553	-2.09
3	0.01333	-2.50
10	0.00429	-4.19
28	0.00330	-4.38
2	0.00025	-5.00
22	-0.00599	-6.14
14	-0.00724	-6.37

What can be seen from the result of the calculation is that comparing to other industries (industrial sectors), the rate of technological progress of the agricultural sector is not very fast. Despite the significant imbalance of the state of technological progress in each PMAR, there are many inland provinces achieving high growth rates. This illustrates that "the transformation of sown area of middle and low productivity" is required. Moreover, the future prospect of agricultural development is going to be impressive.

One final point to be noted is that when using this model to conduct the evaluation, the state of technological progress of some PMAR is not that accurate. This is due to the fact that there have been certain changes in the boundaries of PMARs (for example, Tianjin has incorporated the surrounding poor counties in its jurisdiction). We have tried to exclude those PMARs in question and have then proceeded with the evaluation. The results of the calculation are more or less the same. From this empirical case, one can realize that the evaluation method in this chapter is robust, and the result of the aforementioned example is reliable.

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10

An Estimate of the 1985 GNP of China

Wang Hongchang

An economic variable is a product of some quantity and price in most cases. Prices in China have been administered by government agencies for four decades. Moreover, the same commodity may command different prices for urban and rural people. The state-owned enterprises sell their products in part at official prices and in part at negotiated prices. A buyer may pay additional purchasing cost, i.e., transaction cost, in order to obtain a supply of materials in shortage. Urban inhabitants pay nominal rents only. An organization may buy commodities or even produce commodities to sell to its employees at lower prices.

The profit and loss statement reflects not only the results of business operations, but also transactions in the consumption sphere. It is hazardous to estimate GNP using monetary data as such. However, China has detailed and reliable data in physical term so I propose to calculate the GNP using physical commodity data at China and U.S. prices. The 1985 GNP of China is calculated to be US$615.5 per capita. Differences in quality between commodities produced by the two nations will be explicitly allowed for with several calculated or arbitrarily assigned parameters.

Agriculture

Figures of agricultural commodity production can be found in *Chinese Statistical Yearbook*, 1986, and *Statistical Abstract of the United States*, 1987. Data on agricultural production of China and the United States in 1985 are shown in Table 1.

The U.S. farm output is as given, while the Chinese farm output is multiplied by a scale factor of 0.83. We can find export and import prices of the same subgroup of farm products in the *Summary Surveys of China's Customs Statistics* published for 1985 by the Customs General Administration of the People's Republic of China. The ratio between export and import prices probably reflects the quality differences and is thus referred to as the international quality factor. Taking the simple geometric average of all such ratios of farm products, we obtain the international quality factor of farm products: 0.69. However, the quality of export commodities is usually better than those sold in the domestic market, so we further assign an arbitrary intra-national quality factor: 0.80. Adjusted farm output for China is thus equal to $75.9 \times 0.69 \times 0.80$ = \$41.9 billion.

Mining

See Table 2.

Construction

In 1985, new construction amounting to 355.571 million dollars was completed in the United States. This included both residential and non-residential buildings and non-building construction. The value per square foot of residential buildings was \$45.2. New construction equivalent to 7,866.6 million square feet (\$355,571 million/\$45.2) of residential buildings was put in place.

The value per square foot of manufacturing buildings was \$48.3. Manufacturing buildings are strong in construction but

Table 1 Agricultural production of China and the United States, 1985

	Unit price ($)	United States		China	
		Output	Value (m $)	Output	Value (m $)
Corn	2.41/bu.	8,865m bu.	21,364.7	2,508.4m bu.	6,045.2
Rice, rough	7.9/cwt.	136m cwt.	1,074.4	3,371.4m cwt.	26,634.1
Wheat	3.16/bu.	2,425m bu.	7,663.0	3,149.9m bu.	9,953.7
Sorghum	2.19/bu.	1,113m bu.	2,437.5	205.9m bu.	450.9
Soybeans	5.16/bu.	2,099m bu.	10,830.8	385.5m bu.	1,989.2
Tobacco	1.65/lb.	1,513m lbs.	2,496.5	5,341.3m lbs.	8,813.2
Potatoes	4.08/cwt.	418.5m cwt.	1,705.9	512.5m cwt.	2,091.1
Walnuts	735.2/ton	219,000 tons	161.0	126,000 tons	92.6
Sugarcane	28.2/s. ton	28.2m s. ton	795.4	56.8m s. ton	1,602.7
Sugarbeets	33.9/s. ton	22.6m s. ton	767.0	9.8m s. ton	333.4
Cotton	263/bale	13.4m bales	3,524.2	19.0m bales	4,997.0
Bananas	0.25/lb.	8m lbs.	2.0	1,389.8m lbs.	347.5
Apples	0.12/lb.	7,861m lbs.	909.0	7,960.2m lbs.	955.2
Oranges	9.86/box	162m boxes	1,597.0	49.8m boxes	490.8
Dates	862.1/ton	29,000 tons	25.0	432,000 tons	372.4

Table 1 (Continued)

Pears	269.1/ton	747,000 tons	201.0	2,137,000 tons	575.1
Grapes	171.5/ton	5,605,000 tons	961.0	361,000 tons	61.9
Melons	244.0/ton	238,500 tons	58.2	11,852,000 tons	2,891.9
Pork	0.714/lb.	14.8b lbs.	10,567.2	36.4b lbs.	26,022.7
Beef	1.268/lb.	24.2b lbs.	30,685.6	1.0b lbs.	1,268.0
Mutton	1.4/lb.	357.0m lbs.	499.8	1,306m lbs.	1,828.6
Milk	0.128/lb.	144b lbs.	18,500.0	5.5b lbs.	704.6
Eggs	0.571/dozen	5,701m dozens	3,253.0	7,129.33m dozens	4,070.8
Poultry	0.301/lb.	25.4b lbs.	7,651.0	1.78b lbs.	536.7
Fishery product	0.372/lb.	6,258.0m lbs.	2,326.0	14,931m lbs.	5,554.5
Roundwood	0.057/c.f.	12,745m c.f.	720.6	2,233m c.f.	127.3
Total			130,776.8		108,811.1
Scale factor			1.0		0.83
GNP contribution (b $)			91.5		75.9

Table 2 Mineral products in China and the United States, 1985

	Unit price ($)	United States		China	
		Output	Value (m $)	Output	Value (m $)
Coal	25.6/s.t.	896m s.t.	22,950	961m s.t.	24,615
Natural gas	2.66/1000 c.f.	18.23t c.f.	48,490	0.46t c.f.	1,214.6
Petroleum	25.88/bbl.	3,250m bbl.	84,100	926.7m bbl.	23,983.5
Cement	14.9/s.t.	77.7m s.t.	1,158.1	160.9m s.t.	2,397.6
Salt (common)	17.22/s.t.	39.2m s.t.	675.1	16.3m s.t.	280.8
Iron ore	43.8/l.t.	44.3m l.t.	1,938.5	135.66m l.t.	5,941.9
Asbestos	384/s.t.	63,000 s.t.	24.2	185,268 s.t.	71.1
Gypsum	7.95/s.t.	14.3m s.t.	113.7	5,924,470 s.t.	47.1
Total			159,449.6		58,551.6
Scale factor			1.0		0.37
GNP contribution (b $)			122.8		45.4
Quality factor			1.0		0.3
Adjusted GNP contribution (b $)					13.6

simple in finishing, while residential buildings need not be very strong but are well finished. So the construction costs of those two kinds of buildings are close to each other.

In 1985, the construction value in China amounted to 163 billion yuan. The manufacturing buildings cost 299 yuan per square meter and the residential buildings cost only 177 yuan per square meter. The Chinese manufacturing buildings need to be no less strong than the American ones, but Chinese residential buildings are simply finished. To compare the scale of Chinese construction with that of the United States, we propose to divide the total construction value of 163 billion yuan by the per square meter value of manufacturing buildings, 299 yuan, to obtain the total equivalent floor space of 545 million square meters or 5,868 million square feet.

Table 3 Construction in China and the United States, 1985

	U.S.	China
Floor space (m sq. ft.)	7,866.6	5,868
Scale factor	1.0	0.75
GNP contribution (b $)	182.2	136.7

Manufacturing

See Table 4.

Trade

The GNP generated by agriculture, mining and manufacturing in the United States amounts to $1,010.1 billion, while the trade sector has a GNP contribution of $652.5 billion. The ratio between them is 652.5/1,010.1 = 0.65. Chinese farmers consume about 20 per cent of the food they produce. So only 80 per cent of the

adjusted agricultural output, $41.9 billion, is related to trade, i.e., $33.5 billion. Adding this to the combined mining and manufacturing output, we obtain a sum of $233.3 billion, which is equivalent to 23 per cent of the corresponding U.S. sum. Hence we estimate the Chinese trade output as 652.2 × 0.23 = $150.6 billion. Assuming a quality factor of 0.70, the trade output of China becomes $105.4 billion.

Transportation and Public Utilities

See Table 5.

Sheltering

In 1985, the total value of housing output in the United States was $388.5 billion, which equals personal consumption expenditures for housing, less such expenditures related to hotels, motels, clubs, schools and other group housing. And the total value of housing output less intermediate goods and services consumed ($66.7 billion) equals gross housing product, $321.9 billion. Housing output consists of rents paid by tenants and imputed rents attributed to occupants of owner-occupied dwellings. The United States had a total dwelling space of 13.4 billion square meters with an average annual rent of 388.5/13.4 = $29/square meter. The average GNP generated per square meter was 321.9/13.4 = $24.

China had a total dwelling space of 12.3 billion square meters. Assuming a quality factor of 0.33, the shelter component of GNP was $97.4 billion.

Table 4 Manufacturing in China and the United States, 1985

	Unit price ($)	United States		China	
		Output	Value (m $)	Output	Value (m $)
Beer	127.6/bbl.	93m bbl.	11,868	24m bbl.	3,057.7
Wine	3.72/w.g.	725.3m w.g.	2,695	50.5m w.g.	187.9
Spirits	25.4/t.g.	134m t.g.	3,405	742.9m t.g.	18,869.7
Refrigerators	701.6/unit	5,874,000 units	4,121	1,448,100 units	1,016.0
Washing machines	453.0/unit	4,925,000 units	2,231	8,872,000 units	4,019.0
TV color	429.0/unit	16,894,000 units	7,250	4,352,800 units	1,867.4
TV b.w.	98.0/unit	3,745,000 units	367	12,323,800 units	1,207.7
Radio	29.4/unit	27,528,000 units	808	16,003,200 units	470.5
Telephone	43.9/unit	22,403,000 units	983	2,741,000 units	120.3
Tape recorders	48.5/unit	49,617,000 units	2,408	13,931,000 units	675.7
Steel	416.0/m.t.	88.3m m.t.	36,733	46.79m m.t.	19,465.0
Books	6.88/unit	2,060m units	14,177	5,960m units	41,005.0
Cigarettes	20.02/1000	657b	13,153	1,185b	23,724.0
Trucks	15,240.0/unit	3,465,000 units	52,807	269,000 units	4,100.0
Automobiles	8,561.0/unit	8,185,000 units	70,072	168,200 units	1,440.0

Table 4 (Continued)

Aluminum	1,620/s.t.	15.5m s.t.	25,110	0.58m s.t.	940.0
Copper	1,474/m.t.	8.3m m.t.	12,238	0.43m m.t.	634.0
Calculators	15.44/unit	33,166,000 units	512	14,710,000 units	227.0
Nonrubber footwear	15/pair	301,400,400 pairs	4,500	701,710,000 pairs	10,526.0
Paper	391/s.t.	69m s.t.	26,979	10m s.t.	3,910.0
Man-made fibers	1.07/lb	9,271m lbs	9,956	172m lbs	184.0
Synthetic rubber	2,030/l.t.	2,185,000 l.t.	4,436	178,248 l.t.	362.0
Sugar	0.13/lb	5,969,000 s.t.	1,552	4,970,002 s.t.	1,292.2
P.C.	2,563.4/unit	7.1m units	18,200	114,245 units	293.0
Total			326,561		139,594.1
Scale factor			1.0		0.43
GNP contribution (b $)			795.8		342.2
International quality factor			1.0		0.68
Intranational quality factor			1.0		0.80
Adjusted GNP contribution (b $)					186.2

Table 5 Transportation and public utilities in China and the United States, 1985

	Unit price ($)	United States		China	
		Output	Value (m $)	Output	Value (m $)
Railroads	0.03/t.m.	898b t.m.	26,734	504b t.m.	15,120
Motor vehicles	0.1363/t.m.	600b t.m.	81,780	110b t.m.	14,993
Inland waterways	0.0082/t.m.	348b t.m.	2,854	471b t.m.	3,862
Oil pipelines	0.014/t.m.	562b t.m.	7,824	56.3b t.m.	788
Domestic airways	0.48/t.m.	7.2b t.m.	3,439	0.1b t.m.	48
Automobiles	0.07/p.m.	1,484b p.m.	103,880	33b p.m.	2,310
Airways	0.12/p.m.	335.9b p.m.	39,783	7.2b p.m.	864
Bus	0.07/p.m.	26b p.m.	1,925	98b p.m.	6,860
Railroads	0.05/p.m.	12b p.m.	610.9	150b p.m.	7,500
Passenger transit	0.402/p.	7,889m p.	3,171.4	25,537m p.	10,266
Postal service	0.21/piece	140.1b pieces	28,956	5b pieces	1,050
Telephone	666.7/tel.	151m	100,671	3.1m	2,067
Telegraph	15.25/message	48m	732	219m	3,340
Broadcasting stations	1.35m/station	7,204	9,756.3	415	562

Table 5 (Continued)

Electricity	0.0672/KWH	2,469b KWH	165,917	410.7b KWH	27,599
Gas	5.02/1000BTU	12,616t BTU	63,293	168t BTU	843
Total			641,327		98,072
Scale factor			1.0		0.15
GNP contribution (b $)			374.4		56
Quality factor			1.0		0.70
Adjusted GNP contribution (b $)					39.2

Services

We list employment in the services sectors of China in 1985 as follows:

Geological	1,060,000
Health, athletic, welfare	4,670,000
Culture, education	12,440,000
Science, technology	1,440,000
Banking, insurance	1,380,000
Government, associations	7,990,000
Others	14,190,000
Total	43,170,000

The GNP generated by the services sector could be evaluated by labour costs. As we consistently use the price data of the United States, it may be reasonable to estimate the GNP of China's services sector at U.S. wage rates. For instance, people employed by the retail sector in the United States earned the lowest pay, $15,516 per annum. We could say the Chinese services sector generated an output of 43.17m × 15,516, or $670 billion. However, it would be inconsistent with lower labour productivity in other sectors. Or, we could list the consumption basket of an average employee's family (one employee and one dependent on average) and evaluate its contents at U.S. prices.

Table 6 Agricultural products

Grains	508.7 kg	0.21/kg	$106.8
Vegetable oils	10.2 kg	0.67/kg	6.8
Pork	28.0 kg	3.57/kg	99.9
Beef and mutton	2.6 kg	5.12/kg	13.5
Poultry	3.1 kg	1.68/kg	5.2
Eggs	10.0 kg	1.07/kg	10.7
Fish products	9.8 kg	0.82/kg	8.0
Tea	0.6 kg	2.09/kg	0.7

Table 6 (Continued)

Vegetables	295.0 kg	0.22/kg	63.9
Fruits	22.0 kg	0.25/kg	5.6
Total			321.1
Total × 0.69 (international quality factor) × 0.8 (intra-national quality factor) =			177.25

Table 7 Manufactured products

Sugar	11.3 kg	0.29/kg	$3.2
Cigarettes	122.5 packs	0.40/pack	49.0
Wine	15.4 kg	3.10/kg	47.8
Fabrics	23.3 meters	1.33/meter	31.0
Woolen fabrics	0.6 meter	5.65/meter	3.3
Silk	1.7 meters	3.30/meter	5.7
Shoes	2.8 pairs	15.00/pair	42.3
Bicycle	0.1 unit	297.00/unit	17.8
Radio	0.05 unit	29.40/unit	1.4
Washing machine	0.01 unit	453.00/unit	5.2
Refrigerator	0.002 unit	701.60/unit	1.1
Television	0.023 unit	184.40/unit	4.2
Tape recorder	0.012 unit	48.50/unit	0.6
Knitted clothing	2.70 units	0.72/unit	2.0
Detergents	1.7 kg	1.49/kg	2.5
Confectionery	1.9 kg	2.90/kg	5.5
Blanket	0.03 unit	18.00/unit	0.5
Paper	1.24 kg	0.80/unit	1.0
Kerosene	3.0 kg	0.42/kg	1.3
Total			225.4
Total × 0.68 × 0.8 =			122.6

Table 8 Mining products

Coal	369.0 kg	0.05/kg	$18.4
Salt	16.5 kg	0.02/kg	0.3
Total			18.7

Table 9 Transportation and utilities

Railroads	462 passenger miles	0.05/p.m.	$23.1
Bus	301 passenger miles	0.07/p.m.	21.1
Airways	22 passenger miles	0.12/p.m.	2.6
Waterways	33.2 passenger miles	0.01/p.m.	0.33
Mass transit	49 passengers	0.40/p.	19.7
Gas	4.5 cubic meters	0.18/c.m.	0.8
LPG	1.2 kg	0.15/kg	0.2
Electricity	42.6 KWH	0.0672/KWH	2.86
Natural gas	3 cubic meters	0.18/c.m.	0.5
Total			71.19
Total × 0.70 (international quality factor)			49.83

Shelter 17.2 square meters × 29 × 0.33 (international quality factor) = $164.60;

Personal consumption expenditures of an average employee household = 177.25 + 122.6 + 18.7 + 49.83 + 164.6 = $533;

We estimate the GNP generated by the services sector as 533 × 43,170,000 = $23 billion.

Summary of Results

	GNP 1985 (b $)	
	China	United States
Agriculture	41.9	91.5
Mineral products	13.6	122.8
Construction	136.7	182.2
Manufacturing	186.2	795.8
Transportation and utilities	39.2	374.4
Trade	105.4	652.5
Shelter	97.4	321.9
Services	23.0	1,415.9
Total	643.4	3,957.0
Population (m)	1,045.3	239.3
Per capita GNP	615.5	16,535.7

The GNP Function

Five arbitrary parameters are introduced:

a = intra-national quality factor of agricultural products;
m = intra-national quality factor of manufacturing products;
u = international quality factor of transportation and public utilities;
h = international quality factor of residential buildings;
t = international quality factor of the trade sector.

It is convenient to write the 1985 GNP of China as a function of these five parameters:

$$GNP = 150.5 + 62a + 239.3m + 59.1u + 316.7h + 27.2at + 8.8t + 151.3mt \quad (1)$$

The author has assigned a set of values to these parameters: a, m, u, h, t = 0.8, 0.8, 0.7, 0.33, 0.7 respectively. If we place these values into (1), the GNP will be $558.34 billion. Readers who prefer other parameter values can easily calculate alternative estimates of China's GNP.

Taking partial derivatives of the function with respect to the parameters:

$$dGNP/da = 62 + 27.2t$$
$$dGNP/dm = 239.3 + 151.3t$$
$$dGNP/du = 59.1$$
$$dGNP/dh = 316.7$$
$$dGNP/dt = 27.2a + 8.8 + 151.3m.$$

The function is most sensitive to variation in the value of m, then of h.

Suppose we keep u = 0.7, a = 0.8, t = 0.7, then (1) will become

$$GNP = 262.9 + 345.2m + 316.7h \quad (2)$$

China's 1985 GNP as declared by the State Statistical Bureau was 788 billion yuan which was equivalent to $267.66 billion at the official exchange rate of that year.

This implies a per capita GNP of $256.06. From (2), we obtain

$$267.66 = 262.9 + 345.2m + 316.7h \quad (3)$$

which can be plotted as an equi-GNP curve. There is an infinite number of combinations of h and m values which can produce the GNP of $267.66 billion. For example,

h	-0.53	-0.09	0.004	0.014
m	0.5	0.1	0.01	0.001

Both h and m must be larger than 0, because the Chinese housing sector provides positive service and the manufactured goods made in China have positive value. The other values taken by h (0.004, 0.014) and m (0.01, 0.001) are implausible. In my opinion, h cannot be smaller than 0.33 and m cannot be smaller than 0.8. Thus, 0.33 and 0.8 are the critical values of h and m

respectively and are given the symbols, h* and m*. We can plot a horizontal line, h*=0.33, and a vertical line, m*=0.8. Every point under h*=0.33 or to the left of m*=0.8 is implausible. Equation (3) lies entirely in the implausible region. Readers may assign other values to h* and m*, but (3) will probably still locate in their implausible regions.

We have estimated the 1985 GNP of China as $643.3 billion and can thus plot another equi-GNP curve:

$$643.3 = 262.9 + 345.2m + 316.7h \quad (4)$$

Taking six points on (4) as follows:

h	0.11	0.22	0.33	0.44	0.55	0.66
m	1	0.9	0.8	0.7	0.6	0.5

we find that (4) lies partly in the plausible region, such as (0.33, 0.8), and partly in the implausible region, such as (0.11, 1.0). In fact, we have selected (0.33, 0.8) as the solution to (4).

Similarly, with Equation (1) we can see there is an infinite number of combinations of (a, m, u, h, t) values which will generate any particular level of GNP. If we set the values of the five parameters all to unity, the per capita GNP will amount to $971. Perhaps, it is the upper limit of estimation.

The Ratio of Value Added to Shipments

The methodology used in this study assumes implicitly that the ratios of value added to shipments are similar in China and the United States. My friend, Mr. Li Mingzhe, pointed out the higher consumption of materials and energy in Chinese industry. However, factories usually employ too many people and have large capacity but insufficient supply of materials and energy, so the labour and depreciation costs may also be high. The United States manufactures in 1984 had a ratio of value added to shipments of 43.7 per cent. According to the *Chinese Statistical Yearbook, 1986*, large and medium-sized industrial enterprises produced 318.8

billion yuan of products in 1984 and consumed 170.5 billion yuan of materials, fuels and power. The ratio of value added to production would thus be 46.5 per cent. And the United States is well-known for its petroleum agriculture.

Concluding Remarks

The international or inter-temporal comparison of GNP is after all a comparison of quantities. In order to avoid distortion by administered prices and exchange rates, the author proposes to work directly on physical quantities and the prices of a large market economy. Quality differences in products between China and the United States are explicitly allowed for. He does not claim to have estimated accurately China's GNP in 1985, this study has much to be refined and corrected.

* *Professor Thomas G. Rawski encouraged this study, made many valuable comments and suggestions. In particular, the idea of a GNP function belongs to him.*
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Appendix 1 The Price Ratios

Commodity		Export price	Import price	Px/Pm	
0011	Bovine species	274.46	1,643.33	0.167	Live
0012	Sheep and goats	41.91	1,975.54	0.021	Live
0013	Swine, live	60.72	935.98	0.065	Live
0014	Live poultry	1.61	0.94	1.714	Live
0015	Equine species	299.63	48.11	6.228	Live
0111	Bovine meat fresh	1.43	7.23	0.198	Frzn
0112	Mutton etc. fresh	1.25	4.34	0.288	Chld, frzn
0113	Pork fresh, chld	1.44	3.22	0.447	Frzn
0114	Poultry fresh chld	1.21	0.64	1.891	Frzn
0116	Edible offal fresh	0.97	2.80	0.346	Chld, frzn
0118	Meat nes fresh, chld	1.34	2.41	0.556	Frzn
0121	Pork dried, sltd	2.23	2.96	0.753	Smkd
	Meats, nes, dried, sltd	2.22	0.98	2.270	Smkd
0141	Meat, fish extracts	2.62	4.54	0.577	Juices
0142	Sausages incl	1.66	2.97	0.558	Tinned
0149	Other prepard, presrvd	1.44	2.39	0.603	Meat
0223	Milk and cream	0.49	1.28	0.383	
0224	Milk, cream presrvd	1.19	1.36	0.875	etc.
0240	Cheese and curd	3.40	4.44	0.766	
0251	Eggs in shell, fresh	39.78	99.00	0.402	Presrvd
0252	Eggs not in shell	1.21	6.47	0.187	Fresh, presrvd
0341	Fish fresh, chld	1.81	0.71	2.549	Ex fillets
0342	Fish frzn, exol	1.86	0.18	10.333	Fillets
0343	Fish fillets, fresh	1.14	0.89	1.281	Chld
0344	Fish fillets, frzn	1.39	3.79	0.367	
0350	Fish sltd, dried	4.94	0.72	6.936	Smkd
0360	Shell fish fresh	2.82	2.58	1.093	Frzn
0371	Fish etc. prepard	2.06	3.91	0.527	Presrvd nes
0372	Shell fish prepard	1.58	8.92	0.177	Presrvd
0410	Wheat etc. unmilled	0.12	0.16	0.750	
0421	Rice in husk or husked	0.31	0.29	1.069	
0422	Rice semi-milled	0.22	0.17	1.294	Milled
0430	Barley unmilled	0.18	0.13	1.385	
0440	Maize unmilled	0.12	0.14	0.857	
0459	Other cereals unmilled	0.11	0.27	0.407	
0460	Wheat etc. meal	0.19	0.18	1.056	and flour
0541	Potatoes fresh	0.13	0.96	0.135	
0542	Leguminous veg	0.28	0.43	0.651	Dry
0544	Tomatoes fresh	0.16	2.10	0.076	
0545	Other fresh veg	0.24	1.81	0.133	
0546	Veg simply	0.76	1.47	0.517	Presrvd
0548	Edibles veg nes fresh	0.14	2.06	0.068	Dry
0561	Veg dried exc legumin	2.97	3.15	0.943	
0571	Oranges, mandarin	0.42	0.63	0.667	etc.
0572	Lemons, grapefruit	0.30	0.95	0.316	etc.
0573	Banana, plantain	0.18	0.25	0.720	Fresh, dry
0574	Apples fresh	0.36	0.63	0.571	
0575	Grapes fresh or dried	1.20	0.89	1.348	
0577	Nuts edible, fresh	1.46	0.82	1.780	Dried
0579	Fruit fresh/dried nes	0.46	0.62	0.742	
0586	Fruit temporarily presrvd	0.65	1.12	0.580	
0616	Natural honey	0.71	1.02	0.696	
0741	Tea	2.15	1.50	1.433	
0751	Pepper and pimento	1.09	1.38	0.790	
0752	Spices, ex pepper, pimento	1.04	10.37	0.100	
0811	Bay, fodder, green, dry	0.09	0.52	0.173	
1211	Tobacco not stripped	1.69	2.91	0.581	
1212	Tobacco stripped or part	1.73	2.50	0.692	
2111	Bovine, equine hides, raw	8.61	34.68	0.248	
2112	Calf and kip skins	11.24	34.75	0.323	
2114	Goat and kid skins, raw	3.29	1.43	2.301	
2116	Sheep skin common with wool	4.86	2.17	2.240	
2117	Sheep skin without wool	2.72	1.69	1.609	

2221	Groundnuts, green	0.68	0.60	1.133
2222	Soya beans	0.24	0.35	0.686
2224	Sunflower seeds	0.31	0.47	0.660
2225	Sesame seeds	0.65	0.46	1.413
2226	Rape and colza seeds	0.27	0.21	1.286
2231	Copra	0.48	4.26	0.113
2235	Castor oil seeds	0.31	0.38	0.816
2238	Oil seeds and fruit nes	0.35	0.22	1.591
2440	Cork natural, raw, waste	0.34	1.52	0.224
2450	Fuel wood nes charcoal	0.11	0.03	3.667
2460	Pulpwood, chips, woodwaste	0.38	0.04	9.500
2471	Saw-, veneer-logs conifer	268.71	82.31	3.265
2472	Saw-, veneer-logs non-conifer	294.27	96.952	3.035
2479	Pitprops, poles, piling, etc.	0.23	0.30	0.767
2482	Lumber shaped conifer	104.60	107.84	0.970
2483	Lumber shaped non-conifer	320.73	119.91	2.674
2614	Silk worm cocoons, waste	7.73	14.00	0.552
2631	Raw cotton, excl linter	1.25	0.83	1.506
2681	Wool greasy, fleece-wshed	1.58	2.94	0.537

The simple geometric mean of the above price ratios is approximately 0.69.

2713	Nat calcm phosphates etc.	0.10	0.04	2.500
2731	Bldg, dimension stone	167.41	161.85	1.034
2732	Calcareous stone	0.02	0.59	0.034
2733	Sand, excl metalbearing	0.002	0.38	0.005
2734	Gravel, crushed stone, etc.	0.004	0.35	0.011
2741	Sulp, ex sulp in 52215	0.13	0.18	0.722
2782	Refractory minerals nes	0.06	0.31	0.194
2783	Common salt, etc.	0.02	0.07	0.286
2784	Asbestoes, crde, simply wrkd	0.20	1.09	0.183
2785	Quartz, mica, feldspar, etc.	0.08	3.59	0.022
2789	Minerals crude nes	0.04	0.92	0.043
2860	Uranium, thorium ore, conc	0.61	0.66	0.924
2872	Nickel ores, conc	0.31	8.33	0.037
2873	Aluminum ores, alumina	0.06	0.15	0.400
2875	Zinc ores, conc	0.13	0.28	0.464
2876	Tin ores, conc	5.70	2.48	2.298
2877	Manganese ore, conc	0.04	0.07	0.571
2879	Other non-fer ore, conc	2.94	0.12	24.500
3221	Anthracite, not agglomerated	0.05	0.02	2.500
3222	Other coal, not agglomerated	0.04	0.05	0.800
3339	Petroleum and prod	0.17	0.21	0.810

The simple geometric mean of price ratios of minerals is approximately 0.30.

0483	Macaroni, spaghetti etc.	0.43	1.26	0.341
0484	Bakery prod	1.23	2.04	0.603
0564	Flour etc. of fruit, veg	0.80	0.26	3.077
0565	Veg presrvd, prepard nes	0.78	1.67	0.467
0582	Fruit presrvd by sugar	1.01	1.59	0.635
0583	Fruit jams, jellies etc.	0.73	1.42	0.514
0585	Fruit or veg juice	0.57	1.61	0.354
0589	Fruit prepared, presrvd, nes	1.11	0.86	1.291
0611	Raw sugar	0.35	0.14	2.500
0612	Refined sugar etc.	0.16	0.17	0.941
0620	Sugar candy non-chocolate	1.06	2.92	0.363
0730	Chocolate and prod	2.79	4.30	0.649
1121	Wine of fresh grapes etc.	1.02	3.11	0.328
1122	Cider, perry, mead etc.	1.05	1.90	0.553
1123	Beer, ale, stout, porter	0.33	0.49	0.673
1124	Distilled alcoholic bevs	1.20	3.13	0.383
1222	Cigarettes	15.21	10.58	1.438
2331	Syn rubber etc.	0.95	1.09	0.872
3232	Coke, semi-coke, rtrt crbn	0.09	0.04	2.250
3341	Gasoline, other light oils	0.24	0.46	0.522
3342	Kerosene, other med oils	0.25	0.42	0.595
3343	Gas oils	0.22	0.33	0.667

3344	Fuel oils, nes	0.17	0.26	0.654
3345	Lubs, petroleum oils nes	0.34	1.20	0.283
3351	Petroleum, jelly, mineral wax	0.43	1.50	0.287
3352	Mineral tars and prod	0.20	0.40	0.500
3353	Tar pitch, pitch coke	0.14	0.31	0.452
3354	Petroleum bitumen, coke	0.07	0.24	0.292
3510	Electric current	0.08	0.05	1.600
4232	Soya bean oil	1.15	0.60	1.917
4233	Cotton seed oil	0.56	1.28	0.438
4234	Groundnut (peanut) oil	0.82	1.15	0.713
4236	Sunflower seed oil	0.61	1.13	0.540
4239	Other fixed veg oils, soft	0.65	0.84	0.774
4241	Linseed oil	0.78	0.71	1.099
4245	Castor oil	0.80	1.59	0.503
4249	Fixed veg oils nes	1.11	1.04	1.067
4311	Modified oil	1.22	0.89	1.371
4312	Hydrogenated oil, fat	0.89	1.67	0.533
4313	Fatty acd etc., residues	0.45	2.71	0.166
4314	Animal, veg waxes	2.48	1.34	1.851
5111	Acyclic hydrocarbons	0.36	1.35	0.267
5112	Cyclic hydrocarbons	0.40	0.73	0.548
5113	Halog deriv of hydrocarbons	0.48	1.15	0.417
5114	Hydrocarbons deriv nonhalog	0.95	1.03	0.922
5121	Acyclic alcohols, deriv	0.26	0.76	0.342
5122	Cyclic alcohols, deriv	7.47	1.25	5.976
5123	Phenols, phen alcohols, deriv	1.47	1.24	1.185
5137	Monoacids and deriv	0.62	1.19	0.521
5138	Polyacids and deriv	0.96	0.64	1.500
5139	Oxy-fnct acd, deriv	0.95	1.27	0.748
5145	Amine-fnct cmpd	2.37	1.25	1.896
5146	Oxy-fnct amino-cmpd	4.14	2.48	1.669
5147	Amide-fnct cmpd, exc urea	3.07	1.44	2.132
5148	Other nitrogen-fnct cmpd	1.55	1.33	1.165

5154	Organo-sulp cmpd	3.27	1.47	2.224
5155	Other org-inorg cmpd	0.87	2.10	0.414
5156	Heterocyclic cmpd etc.	1.90	1.60	1.188
5157	Sulphonamides, etc.	7.62	2.05	3.717
5161	Ethers, epoxidee, acetals	2.00	1.27	1.575
5162	Aldehyde etc. fnct cmpd	2.83	1.00	2.830
5163	Inorg esters, salts, etc.	1.04	2.17	0.479
5169	Org chemicals, nes	3.35	5.34	0.627
5222	Inorg acd etc.	0.37	0.08	4.625
5223	Halog, sulp cmpd nonmet	0.96	3.61	0.266
5224	Zinc, irn, lead etc. oxide	0.76	1.32	0.576
5225	Inorg bases etc. nes	1.37	0.25	5.480
5231	Metal cmpd of inorg acd	0.24	0.31	0.774
5232	Other metal cmpd of inorg acd	0.29	0.16	1.813
5233	Metallic acd salts etc.	4.01	0.74	5.419
5311	Syn org dyestuffs	3.41	5.74	0.594
5312	Syn lumin, indigo, lakes	5.97	7.38	0.809
5322	Dye, tann extracts, tannins	1.39	9.10	0.153
5323	Syn tanning prod	0.48	1.62	0.296
5331	Colouring material nes	0.55	1.66	0.331
5332	Printing inks	1.56	4.54	0.344
5334	Varnishes, dispensers etc.	1.09	1.84	0.592
5411	Provitamins and vitamins	9.39	19.62	0.479
5413	Antibiotics in blk	27.75	97.38	0.285
5414	Veg alkaloids and deriv	10.36	29.35	0.353
5415	Hormones, nat, syn in blk	333.22	433.60	0.768
5513	Essentl oil, resinoid, etc.	8.01	5.75	1.393
5514	Mixed perfume substan	11.10	8.60	1.291
5542	Washing preparations etc.	0.54	1.49	0.362
5621	Chem nitrogenous fertilizer	0.22	0.19	1.158
5622	Chem phosphate fertilizer	0.11	0.16	0.688
5629	Fertilizers nes	0.24	0.22	1.091
5721	Prepared explosives	1.15	43.77	0.026

5821	Phenoplasts	0.92	1.96	0.469
5822	Aminoplasts	0.70	1.39	0.504
5823	Alkyds, other polyesters	0.81	1.11	0.730
5824	Plyamides	1.28	1.85	0.692
5825	Polyurethanes	3.54	2.00	1.770
5826	Epoxide resins	3.74	2.75	1.360
5827	Silicones	1.77	3.93	0.450
5829	Other condensation, etc. prod	0.67	0.98	0.684
5831	Polyethylene	0.76	0.64	1.188
5832	Polypropylene	0.79	0.75	1.053
5833	Polystyrene, its copolym	0.65	0.82	0.793
5834	Polyvinyl chloride	0.56	0.79	0.709
5835	Vinyl chloride, acet copolym	0.66	0.89	0.742
5836	Acrylic polymers, etc.	3.91	1.01	3.871
5837	Polyvinyl acet	0.58	0.65	0.892
5839	Other polymrztion etc. prod	1.05	1.37	0.766
5842	Cell nitrates	5.11	4.18	1.222
5849	Other cell deriv, vulc fib	1.00	3.47	0.288
5851	Modified natl resins etc.	0.52	2.25	0.231
5852	Other art plstic mtls nes	2.30	1.55	1.484
5911	Insecticides, for retail	1.22	8.19	0.149
5912	Fungicides, for retail	4.11	3.47	1.184
5913	Herbicides, for retail	1.04	3.41	0.305
5914	Disinfectants, etc., for retail	3.50	3.64	0.962
5921	Starch, inulin, gluen	0.24	0.19	1.263
5922	Albuminoid substan, glues	0.92	1.76	0.523
5981	Chemicals from wood, resin	0.40	3.13	0.128
5982	Anti-knock prepartns etc.	3.30	3.03	1.089
5983	Org chem prod nes	0.50	1.81	0.276
5989	Chem prod, preps nes	0.44	2.28	0.193
6113	Calf leather	3.91	7.90	0.495

6114	Leather bovine nes, equine	0.65	3.11	0.209
6115	Leather sheep, lambs	8.03	30.46	0.264
6116	Leather of other hide, skin	5.64	15.30	0.369
6118	Leather specially finshd	3.47	22.49	0.154
6210	Materials of rubber	0.89	2.07	0.430
6251	Tyres new for motorcars	14.10	30.00	0.470
6252	Tyres, new, bus or lorry	98.75	66.08	1.494
6253	Tyres, new, aircraft	185.00	553.71	0.334
6254	Tyres, new, cycles	3.39	17.96	0.189
6259	Other tyres, tyre cases, etc.	2.49	5.29	0.471
6330	Cork manufactures	0.34	2.03	0.167
6341	Veneer sheets etc.	0.14	0.81	0.173
6342	Plywood of wood sheets	0.41	0.45	0.911
6343	Improved, reconstit wood	0.20	1.32	0.152
6344	Wood-based panels nes	0.55	1.30	0.552
6349	Wood simply shaped nes	0.18	0.42	0.429
6411	Newsprint	0.27	0.39	0.692
6412	Print, writing paper nes	0.60	0.80	0.750
6413	Kraft paper, paperboard	0.50	0.32	0.820
6415	Paper, paperboard, nes	0.32	0.56	0.571
6416	Fib building board	0.13	1.31	0.099
6417	Corrugated paper etc., blk	0.22	0.29	0.759
6418	Coated etc. paper nes blk	0.75	1.78	0.421
6419	Converted paper nes blk	1.86	2.78	0.669
6511	Silk yarn, silkworm gut	18.32	16.55	1.107
6512	Wool, hair yarn, incl tops	14.33	5.36	2.674
6514	Syn fib yarn, blk, monofil	3.78	2.36	1.602
6515	Yarn of 6514 for retail	5.47	4.73	1.156
6516	D'scon syn fib yarn monofil	2.16	6.09	0.355
6517	Regen fib yarn monofil	1.78	2.89	0.616
6518	Yarn of 6517 for retail	2.92	6.40	0.456
6519	Txtl fib yarn nes	3.21	6.77	0.474
6521	Grey woven cotton fabric	0.55	0.62	0.887
6522	Weaven cotton bleached, etc.	0.67	1.34	0.500

6532	Disc syn txtl fabric nes	0.54	0.50	1.080
6534	Disc syn blend fabric nes	0.48	0.78	0.615
6536	Disc regen txtl fabric nes	0.35	0.81	0.432
6581	Bags, sacks of txtl	0.29	0.20	1.450
6592	Carpets etc. knotted	6.67	30.77	0.217
6612	Cement	0.04	0.04	1.000
6712	Pig irn, spiegeleisen etc.	0.13	0.14	0.929
6725	Irn, stl blooms, slabs, etc.	0.23	0.21	1.095
6731	Irn, stl wire rod	0.38	0.26	1.462
6732	Irn, stl bars etc.	0.23	0.26	0.885
6733	Irn, stl profiles etc.	0.31	0.26	1.192
6744	Irn, stl, hvy plate, rolled	0.25	0.26	0.962
6745	Irn, stl, med plate, rolled	0.27	0.26	1.038
6746	Irn, stl thin plate, rolled	0.25	0.35	0.714
6783	Irn, stl tubes, pipes nes	0.36	0.39	0.923
6842	Aluminum, alloys wrkd	1.94	1.33	1.459
6931	Wire cables, ropes etc.	1.09	0.92	1.185
7611	Colour TV receivers	144.18	196.60	0.733

The simple geometric mean of price ratios of manufactured goods is approximately 0.68.

Appendix 2

Zhang Zhongli estimated the per capita GNP of China in the 1880s as $9.40 (Chang 1962, Appendix) and Wu Baosan estimated per capita GNP in 1933 as $12 (*The National Income of China*, 1933) both at current prices. For 1952 and 1957, we have the estimates by K. C. Yeh (1983). The State Statistical Bureau has estimated the GNP of China for every year since 1978. We could convert their results in yuan into dollars by the official exchange rates:

	GNP	Population	Exchange rate	Per capita GNP	
	(billion yuan)	(billion)	(yuan/dollar)	(yuan)	(dollars)
1952	74.5	0.57482	3.30	129.67	39.29
1957	112.7	0.64653	3.36	174.28	51.87
1978	348.2	0.96259	1.72	361.73	210.31
1979	399.8	0.97542	1.55	409.87	264.44
1980	447.0	0.98705	1.49	452.86	303.93
1981	477.3	1.00072	1.67	476.96	285.60
1982	519.3	1.01590	1.85	511.17	276.31
1983	580.9	1.02764	1.97	565.28	286.94
1984	696.2	1.03876	2.24	670.22	299.21
1985	855.8	1.05044	2.97	814.71	274.31
1986	969.6	1.06529	3.49	910.17	260.80
1987	1,130.1	1.08073	3.73	1,045.68	280.34
1988	1,398.4	1.09614	3.72	1,275.75	342.94
1989	1,578.9	1.11191	3.72	1,419.99	381.72
1990	1,740.0	1.14333	5.20	1,521.87	292.67

The *Statistical History of the United States* has a series of U.S. per capita GNP in 1958 dollars since 1869-1878. Using the U.S. GNP deflator, we could connect the Chinese data to this series for comparison:

	Per capita GNP in 1958 dollars		
	U.S.	China	U.S./China
1869-79	531		
1879-88	774	35.47	21.8
1933	1,126	30.53	36.9
1952	2,517	44.90	56.1
1957	2,642	53.20	49.7
1978	4,789	99.67	48.0
1979	4,866	115.48	42.1
1980	4,798	121.57	39.5
1981	4,840	104.23	46.4
1982	4,694	95.28	49.3
1983	4,815	95.33	50.5
1984	5,076	95.59	53.1
1985	5,166	84.93	60.8
1986	5,309	79.03	67.2

Although both the U.S. and Chinese results are rough estimates with many problems in data and methodology, we can still make two observations: a wide gap already existed between the U.S. and Chinese per capita GNP in the 1870s, and its size has grown further in the last 120 years.

The industrial revolution made steam engines work for man. In 1850, the United States had 2,121,000 HP of steam engines. Foreign steamships called frequently at Chinese ports beginning in the 1830s, but China herself had no steam engine in 1850. Before the industrial revolution, man domesticated animals, water and wind power to help him work. In 1867, the United States had 28,636,000 heads of cattle, 6,820,000 horses and 1,000,000 mules. With a population of 37,376,000, everybody had one large animal on average. In contrast, the average Chinese had only 0.11 large animal in 1949. The French geographer Pierre Gourou noticed in

1948: "What is more, they make little use of work animals; the essential farm tasks are done by hand. Indeed, some villages in the Yangtse delta do not have a single draft animal" (Gourou 1948).

Per capita energy consumption may serve as an indicator of industrialization. The per capita energy consumption of the United States was 9,577 kilograms of standard coal in 1984, while that of China was 683 kilograms. The total area of the United States is 97.6 per cent of China's. But both arable and forest lands in the United States are twice as large as those in China. The Americans practise mixed farming. In 1982, the value of farm products sold was $131.6 billion, of which $61.9 billion were crops and $69.4 billion were livestock, poultry and their products. Crops included hay, fruits, nuts, nursery products and forest products in addition to grains, oil-bearing crops, vegetables, sugar crops, fibres, tobacco, etc. Farms were classified in accordance with their principal products, such as grain farms, fruit and nut farms, cattle, hog and sheep farms, dairy farms, poultry farms, etc. Oranges are the principal commodity of Florida. Cattle is the principal commodity of eight mountain states. Connecticut is a producer of eggs and dairy products. Georgia, Alabama, Delaware and Maryland specialize in poultry. The United States has 986.8 million acres of farmland, of which only 383 million acres were used for crops in 1982. Lands not used or not suitable for crops can be shifted to pasture, tree or other uses. Since the New Stone Age China had developed an intensive agriculture. People grew grains and vegetables on the best lands, to the neglect of hills, mountains, forests, pastures and cattle-raising. The United States had more than 105 million heads of cattle in 1986 and produced more than 10 million tons of beef and veal. China had 91.7 million heads of cattle but produced only 589,000 tons of beef. China has not made full use of the land resources to produce more feed for cattle and plant more trees for fruits, nuts and lumber. Between 1886 and 1985, the average annual growth rate of per capita GNP in 1985 dollars was 1.92 per cent for the United States and 1.70 per cent for China, using the 1985 per capita GNP estimated by this study, $615.5, or 190.56 in 1958 dollars. There have been several major wars and disasters in the period; in all, 20 years may have been wasted by those events. If there had been no waste of time, the average annual growth rate would have been 2.12 per cent, and the 1985 per capita GNP of China would have been 290.12 (1958 dollars) or 937.08 (1985 dollars).

Appendix 3 A Reply to the Comments by Messrs. T. T. Hsueh and K. Y. Tsui

I contributed the paper, "An Estimate of the 1985 GNP of China" to the Conference on "Productivity, Efficiency and Reform in China's Economy." Messrs. Hsueh and Tsui have kindly read the paper and made valuable comments and suggestions on it. I would like to elucidate a few points thereof.

To make international comparisons between the per capita GNP of China and another nation, we have two problems: to evaluate the GNP of China and express it in terms of some international monetary units, for example, the U.S. dollar. The concept of purchasing power parity (PPP) as by Irving Fisher and Professor Kravis could be useful in theory for the second problem and irrelevant to the first. However, the PPP methodology applied to the case of China encounters many obstacles and proves to be not very helpful.

In October 1979, Professor Kravis visited China and gathered prices in five cities and rural areas adjacent to three of them. For grain products, the retail prices were reduced by 7 per cent and for most other foods by 15 per cent to approximate national average prices.

The urban inhabitants in China paid a part of the food price, the residual part was paid by the government. To prevent the very cheap grains in the city from returning to rural area, grain coupons were issued to city dwellers. In 1979, farmers sold grains to the state at a price 30.5 per cent higher than that in 1978, but the state sold it to city dwellers at a price even 0.5 per cent lower than that in the previous year. Ninety-three price ratios were calculated, of which 20 ratios were those of transportation, communications, recreation, education, medical care, etc. The services prices for most urban inhabitants were very cheap, because the state paid a large part of them.

If one evaluate the purchasing power of the *Renminbi* on the basis of the cheap prices paid by urban inhabitants, the result will be over-valuation.

As China had not published her 1975 GNP but had published the 1976 per capita national income as \$139, Professor Kravis converted it to 270 yuan using an exchange rate of 1.94 yuan per dollar and treated it as the starting point of 1975 GNP estimation. As most prices of products and material inputs were administered, the income calculated for each sector was rather arbitrary. At that time, many consumers' and producers' goods were in short supply. People spent much time and energy and even paid additional transaction costs in order to obtain the desired goods. On the other hand, there were also a large quantity of unsalable goods, but no enterprise had the competence or motivation to lower their prices.

As Professor Kravis explained, his approach was to make comparisons of prices in order to derive quantity ratios. For any one item,

$$Qc/Qus = PcQc/PusQus/Pc/Pus \tag{1}$$

PPP was but a means to obtain the end, quantity ratio. The international comparison of GNP is a comparison of quantities after all. And the Chinese statistical data are strong in quantities but weak in prices and financial accounting. Why not make quantity comparisons directly?

Multiply both sides of (1) by Pus/Pus, we have

$$QcPus/QusPus = PcQc/Qus/Pc = Qc/Qus \tag{2}$$

I use Equation (2) instead of (1) to base the calculation on a firmer bedrock. Equation (2) has at least two advantages. The evaluation of China's GNP is made in terms of market prices instead of administered prices. I use the vast resources of physical quantity data instead of a few administered prices as the basis of international comparison.

I assume that differences between export and import prices reflect quality differences. Messrs. Commentators called my attention to the possible distortion of export prices by subsidies. I assume export prices were determined by the international market. The government could make the exporters more profitable but the latter are price-takers in the world market.

Messrs. Commentators are right in pointing out the arbitrariness of the intra-national quality factors. To enhance the quality of export goods may be the practice of many countries. They are at least better packaged. Perhaps, I could rather give up the intra-national price factors. In that case, the 1985 GNP of China will be \$687.42 billion, and the per capita GNP will be \$657.6.

11

Overview of Productivity Performance in Taiwan's Industrial Sector

Chi-yuan Liang

I. Introduction

In the past three decades, Taiwan has become one of the most dynamic economies in the world. Its gross national product grew at 9.2 per cent per annum between 1961 and 1988. Discovering the causes of Taiwan's fast economic growth is quite an interesting topic, since it not only provides clues for Taiwan's continuous economic growth in the future, but the lessons of the "Taiwan Experience" might also be useful to other developing countries.

There have been numerous attempts made to analyse the sources of Taiwan's economic growth and the results have also been fruitful.[1] Basically, the relevant studies, whether at the sectoral or aggregate level, may be classified into either a demand-side approach or a supply-side approach. The studies adopting a demand-side analysis attribute Taiwan's economic growth to the expansion of domestic demand and foreign demand. The studies following the supply-side approach with the use of production functions commonly allocate the growth of the economy or an industry to the growth of factor inputs and total factor productivity (TFP), or technical change.

Most of the supply-side research has mainly covered the manufacturing and agricultural sectors. The other sectors, such as services, utilities, mining, construction and transportation are ignored. Moreover, most of these papers discuss only the relationship between value added and factor inputs, such as labour and capital. In fact, the intermediate input makes up a larger share of total cost than capital and labour. The substitutability and complementarity between intermediate input and capital, and between intermediate input and labour are so important that it is inappropriate simply to ignore them. In addition, since the 1973 Oil Shock, the effect of changes in energy prices and quantities on output growth and the relationship between energy input and other factor inputs have become a world-wide concern. Consequently, the conventional value added model should be replaced by a model in which the change in output is explained by the change in factor inputs, including capital, labour, energy and other intermediate input, and change in total factor productivity or technical change.

Furthermore, in previous studies, the heterogeneity within a specific category of input is not taken into account. For example, the nature of labour input is different according to working status such as manager, clerk, engineer, skilled labour and unskilled labour. Within the capital input, the nature of such inputs as construction, machinery, transportation equipment, land and inventories also varies. To measure accurately the contribution of factor inputs to the growth of output and the changes in productivity, every factor input should be further decomposed before being summed up, using appropriate weights.

By improving the conventional research framework mentioned above, the objective of this chapter is to measure the growth of output, inputs and productivity change by different industries and to analyse the sources of growth in output and total factor productivity with respect to Taiwan's 25 industries during 1961-1981. In addition, an international comparison among the United States, Japan and Taiwan is conducted. Finally, policy implications are drawn from the findings.

For this purpose, a translog or Tornqvist index, which theoretically approximates Irving Fisher's ideal index, is employed. The translog index is derived from the translog production function, which is a much more general functional form than the conventional Cobb-Douglas and CES (Constant Elasticity of Substitution) functions.

The outline of the rest of this chapter is as follows: Section II, Methodology; Section III, Data Compilation; Section IV, Results; Section V, Conclusion and Suggestions.

II. Methodology

Following Gollop and Jorgenson (1980), we measure sectoral productivity by using a translog production function:[2]

$$\begin{aligned} lnQ = {} & ln\alpha_0 + \alpha_T T + \alpha_K lnK + \alpha_L lnL + \alpha_E lnE + \alpha_M lnM \\ & + \frac{1}{2}\beta_{KK}(lnK)^2 + \beta_{KL} lnK\, lnL + \beta_{KE} lnK\, lnE \\ & + \beta_{KM} lnK\, lnM + \beta_{KT} T\, lnK + \frac{1}{2}\beta_{LL}(lnL)^2 \\ & + \beta_{LE} lnL\, lnE + \beta_{LM} lnL\, lnM + \beta_{LT} T\, lnL \\ & + \frac{1}{2}\beta_{EE}(lnE)^2 + \beta_{EM} lnE\, lnM + \beta_{ET} T\, lnE \\ & + \frac{1}{2}\beta_{MM}(lnM)^2 + \beta_{MT} T\, lnM + \frac{1}{2}\beta_{TT} T^2. \end{aligned} \tag{1}$$

Output (Q) is a function of the logarithms of capital (K), labour (L), energy (E), intermediate input (M) and time (T) which is a proxy for the level of technology. The production function is assumed to exhibit constant returns to scale, so that a proportionate change in all inputs results in a proportionate change in output. The translog production function is characterized by constant returns to scale if and only if the parameters satisfy the following conditions:[3]

$$\alpha_K + \alpha_L + \alpha_E + \alpha_M = 1 \quad (2)$$

$$\beta_{KK} + \beta_{KL} + \beta_{KE} + \beta_{KM} = 0 \quad (3)$$

$$\beta_{LK} + \beta_{LL} + \beta_{LE} + \beta_{LM} = 0 \quad (4)$$

$$\beta_{EK} + \beta_{EL} + \beta_{EE} + \beta_{EM} = 0 \quad (5)$$

$$\beta_{MK} + \beta_{ML} + \beta_{ME} + \beta_{MM} = 0 \quad (6)$$

$$\beta_{KT} + \beta_{LT} + \beta_{ET} + \beta_{MT} = 0. \quad (7)$$

Differentiating Equation (1) with respect to capital (K), labour (L), energy (E) and intermediate input (M) respectively, we can derive the value share equations of capital, labour, energy and intermediate inputs as in the following equations:

$$S_K = \alpha_K + \beta_{KK} lnK + \beta_{KL} lnL + \beta_{KE} lnE + \beta_{KM} lnM + \beta_{KT} T \quad (8)$$

$$S_L = \alpha_L + \beta_{LK} lnK + \beta_{LL} lnL + \beta_{LE} lnE + \beta_{LM} lnM + \beta_{LT} T \quad (9)$$

$$S_E = \alpha_E + \beta_{EK} lnK + \beta_{EL} lnL + \beta_{EE} lnE + \beta_{EM} lnM + \beta_{ET} T \quad (10)$$

$$S_M = \alpha_M + \beta_{MK} lnK + \beta_{ML} lnL + \beta_{ME} lnE + \beta_{MM} lnM + \beta_{MT} T. \quad (11)$$

Similarly, differentiating Equation (1) with respect to time (T), we can derive the rate of technical change or total factor productivity change as:

$$R_T = \alpha_T + \beta_{KT} lnK + \beta_{LT} lnL + \beta_{ET} lnE + \beta_{MT} lnM + \beta_{TT} T. \quad (12)$$

If we consider data at any two discrete points of time, say T and T-1, the average rate of technical change can be expressed as the difference between successive logarithms of capital, labour, energy and intermediate input with weights given by average value shares:[4]

$$\begin{aligned} \overline{R_T} = {} & lnQ(T) - lnQ(T-1) - \overline{S_K}\,[lnK(T) - lnK(T-1)] \\ & - \overline{S_L}\,[lnL(T) - lnL(T-1)] - \overline{S_E}\,[lnE(T) - lnE(T-1)] \\ & - \overline{S_M}\,[lnM(T) - lnM(T-1)] \end{aligned} \quad (13)$$

where

$$\overline{S_K} = \frac{1}{2}\,[S_K(T) + S_K(T-1)] \quad (14)$$

$$\overline{S_L} = \frac{1}{2}\,[S_L(T) + S_L(T-1)] \quad (15)$$

$$\overline{S_E} = \frac{1}{2}\,[S_E(T) + S_E(T-1)] \quad (16)$$

$$\overline{S_M} = \frac{1}{2}\,[S_M(T) + S_M(T-1)] \quad (17)$$

$$\overline{R_T} = \frac{1}{2}\,[R_T(T) + R_T(T-1)]. \quad (18)$$

We refer to this expression as the average rate of technical change, and R_T as the translog index of the rate of technical change or the translog index of the rate total factor productivity change. The translog index is sometimes called the discrete version of the Divisia index or the Tornqvist index.[5]

Similarly, we can consider specific forms for the functions defining industry aggregate capital (K), labour (L), energy (E) and intermediate input (M). For example, the intermediate input aggregate can be expressed as a translog function of m individual intermediate inputs:

$$\begin{aligned} lnM = {} & \alpha_1 lnM_1 + \alpha_2 lnM_2 + \ldots + \alpha_m lnM_n + \frac{1}{2}\beta_{11}(lnM_1)^2 \\ & + \beta_{12} lnM_1\, lnM_2 + \ldots + \frac{1}{2}\beta_{mm}(lnM_m)^2. \end{aligned} \quad (19)$$

The translog intermediate input is characterized by constant returns to scale, if and only if,

$$\alpha_1 + \alpha_2 + \ldots + \alpha_m = 1 \quad (20)$$

$$\beta_{11} + \beta_{12} + \ldots + \beta_{1m} = 0 \quad (21)$$

$$\beta_{1m} + \beta_{2m} + \ldots + \beta_{mm} = 0. \quad (22)$$

The value share of individual intermediate inputs can be expressed as

$$S_{Mi} = \alpha_i + \beta_{1i} lnM_1 + \beta_{2i} lnM_2 + \ldots + \beta_{mi} lnM_i,\ i = 1, 2, \ldots, m. \quad (23)$$

Considering the data at discrete points in time, the difference between successive logarithms of intermediate input is a weighted average of differences between successive logarithms of individual intermediate inputs with weights given by average value shares:

$$lnM(T) - lnM(T-1) = \sum_{i=1}^{m} \overline{S}_{Mi} [lnM_i(T) - lnM_i(T-1)], \quad (i = 1, 2, \ldots m) \quad (24)$$

where

$$\overline{S}_{Mi} = \frac{1}{2} [S_{Mi}(T) + S_{Mi}(T-1)],\ (i = 1, 2, \ldots m). \quad (25)$$

Similarly, if aggregate capital, labour and energy input are translog functions of their components, we can express the difference between successive logarithms as follows:

$$lnK(T) - lnK(T-1) = \sum_{i=1}^{k} \overline{S}_{Ki} [lnK_i(T) - lnK_i(T-1)], \quad (i = 1, 2, \ldots k) \quad (26)$$

$$lnL(T) - lnL(T-1) = \sum_{i=1}^{l} \overline{S}_{Li} [lnL_i(T) - lnL_i(T-1)], \quad (i = 1, 2, \ldots l) \quad (27)$$

$$lnE(T) - lnE(T-1) = \sum_{i=1}^{e} \overline{S}_{Ei} [lnE_i(T) - lnE_i(T-1)], \quad (i = 1, 2, \ldots e) \quad (28)$$

where

$$\overline{S}_{Ki} = \frac{1}{2} [S_{Ki}(T) + S_{Ki}(T-1)],\ (i = 1, 2, \ldots k) \quad (29)$$

$$\overline{S}_{Li} = \frac{1}{2} [S_{Li}(T) + S_{Li}(T-1)],\ (i = 1, 2, \ldots l) \quad (30)$$

$$\overline{S}_{Ei} = \frac{1}{2} [S_{Ei}(T) + S_{Ei}(T-1)],\ (i = 1, 2, \ldots e). \quad (31)$$

We refer to these expressions for aggregate intermediate input, capital input, labour input and energy input as translog indexes of intermediate input, capital input, labour input and energy input.

It is also noted that, although we are not going to estimate the parameters of the translog production function specified in Equation (1), defining indexes appropriate for discrete points of time is needed according to Nelson (1973) and Usher (1974). Furthermore, Diewert (1976) has shown that if the translog production function is a homogeneous translog, then the translog quantity index will be exact. This provides a theoretical foundation for using the translog index in productivity analyses.

III. Data Compilation

The observation period of analysis runs from 1961 to 1981. The industries covered are the following 25 sectors: agriculture, mining, utilities, construction, transportation and communications, services and 19 manufacturing sectors. Owing to space limitation, we select the manufacturing sector as an example to demonstrate how the data are compiled.

Capital Input

Capital input is decomposed into five classes: (1) construction (K_1), (2) machinery (K_2), (3) transportation equipment (K_3), (4) land (K_4), and (5) inventories (K_5). Data on quantities and value shares in total capital input of various kinds of capital are needed to calculate the translog index of capital input. The quantity of machinery, transportation equipment and construction is measured by the following equation:

$$K_i(T) = K_i^l(T) - D_i(T), \quad i = 1, 2, 3 \tag{32}$$

and

$$K_i^l(T) = K_k^l(T-1) + I_i(T), \quad i = 1, 2, 3 \tag{33}$$

where

$K_i^l(T)$: gross capital stock of type i (at 1976 prices) in year t;
$K_i(T)$: capital stock of type i (at 1976 prices) in year t;
$I_i(T)$: gross investment type i (at 1976 prices) in year t;
$D_i(T)$: capital allowance of type i (at 1976 prices) in year t.

Data on K_i^l comes from the *1975 Survey of Industrywide Fixed Capital Stock in Taiwan Area*, published by the Council on Economic Planning and Development and from the *Industry and Commerce Survey* of 1971. $I_i(T)$ and its deflator P_{Ii} are obtained from the Directorate General of Budget, Accounting and Statistics (DGBAS) of the Executive Yuan.

Since it is well-known that the capital allowance figures from the *National Income Account* are often overestimated, we adjust the depreciation data from the *National Income Account* by multiplying

it by 0.64, a figure obtained from the Council on Economic Planning and Development to estimate the actual capital allowances.

The data on the quantity and the value of land are estimated by interpolating and extrapolating the data from the *Census Report of Industry and Commerce in Taiwan Area* in various years. Similarly, we interpolate and extrapolate the data from the same census data to obtain the data on the value of inventories. We then deflate the value of inventories by an output price index to estimate the quantity of inventories or the value of inventories at constant prices. The output price index is derived from the *National Income Account* and the *Production Index of Industry in Taiwan* compiled by the Ministry of Economic Affairs.

For calculating the translog index of capital input, the data on shares of individual capital input S_i are also needed. S_i is obtained by multiplying the quantity of capital input K_i with the rental price capital input P_{ki} and dividing by the sum of P_{ki}*K_i, i.e., total property compensation. According to Gollop and Jorgenson (1980), the rental price of the ith type of capital input takes the following form:

$$P_{Ki} = \frac{1-\mu(T)\,Z_i(T)}{1-\mu(T)}\,[P_{Ii}(T-1)\,(1-\mu(T))\,R(T) + \delta P_{Ii}(T) - (P_{Ii}(T) - P_{Ii}(T-1))] + P_{Ii}(T)\,\tau_i(T), \quad i = 1, 2, 3, 4, 5 \tag{34}$$

where

$\mu(T)$: the enterprise income tax rate;
$Z_i(T)$: the present value of capital allowance of type i;
$P_{Ii}(T)$: the price index of gross investment of type i;
$R(T)$: the nominal rate of return;
δ: the depreciation rate;
τ_i: the property tax rate of capital of type i.

By Equation (34), the rental price of capital input of type i is the sum of the nominal return to capital $P_{Ii}(T-1)^* \cdot R(T)$ and depreciation $\delta P_I(T)$, less capital gain $P_{Ii}(T) - P_{Ii}(T-1)$, multiplied by the adjustment factor of business income tax and present value of capital allowance $\frac{1-\mu(T)\,Z_i(T)}{1-\mu(T)}$, to be added to the property tax on capital of type i $P_{Ii}(T)\,\tau_i(T)$.

Enterprise income tax rate $\mu(T)$ comes from the *National Income Account*. The property tax rate of capital of type i, τ_i, is compiled from the *Fiscal Statistical Yearbook* published by the Ministry of Finance. Based on the straight-line depreciation method, the depreciation rate δ equals the reciprocal of the years of asset life n_i, which is obtained from the DGBAS. The present value of a dollar of capital allowance of type i, $Z_i(T)$, can be derived using the following equation:

$$Z_i(T) = \frac{S_i(T)}{n_i}. \tag{35}$$

The present value of a dollar of investment goods of type i may be estimated as follows:

$$S_i(T) = \frac{(1+r)^{n_i} - 1}{r(1+r)^{n_i} - 1} \tag{36}$$

where n_i is the number of years of asset life.
r is the interest rate.

The interest rate r employed is the weighted average of interest rates of different terms obtained from the *Monetary Statistical Monthly*. The price indexes of machinery, transportation equipment and construction are compiled from the *1975 Survey of Fixed Capital Stock in Taiwan*, published by the Council on Economic Planning and Development. The output price indexes of machinery, transportation equipment and construction sectors are derived from the *National Income Account* and the *Production Index of Industry in Taiwan* published by the Ministry of Economic Affairs. Finally, the rate of return R(T) is calculated using the following equation:

$$R(T) = \frac{PC - \sum_{i=1}^{5}\left[\frac{1-\mu(T)\,Z_i(T)}{1-\mu(T)}\left(\delta P_{Ii}(T) - P_{Ii}(T)\right)\right]K_i}{\sum_{i=0}^{5}\left(1-\mu(T)\,Z_i(T)\right)P_{Ii}(T-1)\,K_i(T)} \tag{37}$$

The property compensation (PC), which is comprised of rent, interest, profit and capital allowance should by definition be equal to the total sum of the values of individual capital inputs. Data on the property compensation is available from the *National Income Account*. The data of $P_{Ki}(T)$ and R(T) are obtained by solving Equation (34) and Equation (37) simultaneously.

The time-series data on the value share of capital in total output are compiled from the *National Income Account* and are adjusted using the *1976 Input-Output Table*. The adjustment is undertaken to subtract the wage compensation of self-employed workers from the property compensation, *National Income Account*. The *1976 Input-Output Table* is used for the adjustment because it was the most up-to-date *Table* when this study was undertaken.

Labour Input

According to the *Census Report of Industry and Commerce in Taiwan Area*, the labour is classified into four groups: (1) managers and clerks; (2) engineers and technicians; (3) skilled labour; and (4) non-skilled labour. The data for the aggregate quantity of labour input is provided by DGBAS. The structure of labour input, classified by the above four types of labour, is derived by interpolating the *Census* data for the years 1961, 1966, 1971 and 1976; the 1981 data are from the *Labor Statistics Monthly*, published by DGBAS.

The data pertaining to the breakdown of labour compensation are compiled by the following procedures: (1) interpolating the *Census* data of 1961, 1966, 1971 and 1976, and the 1981 data from *Labor Statistics Monthly*, to arrive at preliminary estimates of four types of wage P_{Li}; (2) adjusting P_{Li} with the *Adjustment of the Manufacturing Wage Statistics in Taiwan Area* to obtain P_{Li}'; (3)

multiplying L_i with P_{Li}' to get the labour compensation; (4) adjusting the labour compensation $L_i \cdot P_{Li}'$ with the *National Income Account* to get the adjusted labour compensation; and (5) using the adjusted labour compensation and L_i to get the wage rate P_{Li}.

Similarly, the value share of labour compensation in total output is derived from the *National Income Account*, it is then adjusted by adding the compensation of self-employed works to labour compensation.

Intermediate Inputs

There are five categories of intermediate inputs: agricultural intermediate input, industrial intermediate input, transportation's intermediate input, service intermediate input and imported intermediate input.

The data on value shares of each intermediate input during 1961-1981 are then obtained by interpolating and extrapolating relevant data from the *Input-Output Table* in 1961, 1966, 1969, 1971 and 1976.

Similarly, the value and value share of the intermediate input as a whole come from the *National Income Account* and are adjusted using the *1976 Input-Output Table*. Since the data on intermediate input in the *National Income Account* include energy input, we subtract the value of energy input (see next section) from the value of intermediate input.

The value of each detailed intermediate input (at current prices) is the product of the value share of the intermediate input S_{Mi} and the value of total intermediate input M_i. Finally, the value of each intermediate input at constant prices is produced by deflating the value of each intermediate input with the corresponding deflator.

The sources for those deflators are as follows: (1) agricultural intermediate input: *Statistical Yearbook*, DGBAS; (2) industrial intermediate input: *Commodity Price Statistics Monthly*, DGBAS; (3) service intermediate input: *1981 National Income Account*; (4) transportation's intermediate input: *1981 National Income Account*;

(5) import intermediate input: *Monthly Statistics of Exports and Imports*, the Ministry of Finance.

Energy Input

The translog index of energy input consists of coal, oil products, natural gas and electricity. The quantities of various types of energy consumed are available in *Energy Balance in Taiwan, R.O.C.* published by the Energy Committee. The price for each type of energy is mainly compiled from the *Taiwan Energy Statistics*, Energy Committee and the *Commodity Price Statistics Monthly*, DGBAS.

Again, for consistency, the value shares of various types of energy are adjusted using the *1976 Input-Output Table*.

Real Total Output and Value Added

The index of real total output comes from the *Statistics of Industrial Production*. The deflator of total output is derived from the *National Income Account* and the *Statistics of Industrial Production*. The real value added is the product of the value of real total output and the sum of value shares of capital input and labour input.

IV. Results

The Growth of Real Output and Value Added

The Growth in Sectoral Real Output

The estimated growth rate of sectoral real output during 1961-1981 is presented in column 1, Table 1. The following conclusions emerge:

(1) The manufacturing sectors had relatively higher growth rates in real output than the non-manufacturing sectors. The manufacturing sector as a whole grew by 14.2 per cent per annum in terms of real output during 1961-1981. The output growth rates of the non-manufacturing sectors were as follows: construction (12.5

per cent), transportation (11.2 per cent), public utilities (10.9 per cent), services (9.3 per cent), agriculture (3.2 per cent) and mining (2.2 per cent).

(2) The relatively outstanding performers in manufacturing were as follows: electrical machinery (27.1 per cent), miscellaneous manufacturing (22.0 per cent), transportation equipment (21.0 per cent), chemicals (18.7 per cent), clothing and apparels (18.5 per cent), rubber (16.9 per cent), textiles (14.8 per cent) and metal (14.7 per cent). On the end, the relative poor growth performers were wood and bamboo (7.7 per cent), printing (8.8 per cent) and beverages (9.3 per cent).

(3) Except for mining, construction, leather and furniture, all of the sectors' growth rates decelerated after the 1973 Oil Shock. For instance, the growth rate of manufacturing as a whole dropped from 16.93 per cent before the Oil-Shock period (1961-1973) to 10.22 per cent of the Post-Oil-Shock period (1973-1981).

Table 1 The growth of real total output and value added, 1961-1981 (%)

Industry	Total output growth			Value added growth		
	1961-81	1961-73	1973-81	1961-81	1961-73	1973-81
Agriculture	3.15	3.72	2.28	3.32	3.70	2.75
Mining	2.15	1.80	2.67	1.30	2.25	-0.12
Manufacturing	14.24	16.93	10.22	12.78	15.11	9.28
Food	12.16	14.46	8.70	8.66	5.47	13.45
Beverages	9.34	12.33	4.86	8.75	10.47	6.17
Textiles	14.84	19.75	7.47	14.99	18.89	9.13
Clothing	18.48	22.64	12.26	14.91	16.50	12.54
Leather	12.84	11.68	14.57	13.18	12.66	13.96
Wood	7.68	15.37	-3.86	5.73	13.56	-6.02
Furniture	9.35	9.34	9.37	8.51	8.44	8.62
Paper	10.95	11.66	9.88	10.11	11.02	8.75
Printing	8.77	11.88	4.11	9.04	10.94	6.21
Chemicals	18.73	23.08	12.20	16.41	22.49	7.29
Rubber	16.89	22.23	8.89	16.70	22.64	7.77
Pet. and coal	12.42	17.97	4.10	7.16	15.58	-5.48
Non-metallic	11.70	11.99	11.26	9.80	11.41	7.38
Basic metal	14.22	15.40	12.45	12.40	12.83	11.75
Metal prod.	14.73	16.87	11.53	13.29	17.00	7.71
Machinery	14.20	17.14	9.78	12.15	14.22	9.04
Elec. mach.	27.12	37.36	11.77	25.39	34.85	11.19
Trsp. eqpt.	21.03	26.20	13.27	19.69	25.27	11.33
Misc. mfg.	22.04	24.32	18.63	20.98	22.52	18.68
Utilities	10.93	13.35	7.31	8.97	10.08	7.30
Construction	12.49	12.06	13.14	12.07	10.10	15.01
Trsp. comm.	11.24	12.65	9.12	11.84	14.04	8.54
Services	9.30	10.64	7.28	9.75	11.57	7.02

The Growth in Sectoral Real Value Added

Table 1 reports the estimated growth rate of sectoral real value added during 1961-1981. From this we conclude:

(1) In most cases, the sectors with high growth rates of real output were also the sectors of high growth rates in real value added. The manufacturing sector as a whole, which registered a 12.8 per cent annual growth rate in real value added during 1961-1981, outpaced all of the non-manufacturing sectors. Among the non-manufacturing sectors, the ranking in terms of growth rates of real value added was as follows: construction (12.1 per cent), transportation (11.8 per cent), services (9.8 per cent), public utilities (9.0 per cent), agriculture (3.3 per cent) and mining (1.3 per cent).

(2) The relatively outstanding growth performers in the manufacturing sector were the electrical machinery (25.4 per cent), miscellaneous manufacturing (21.0 per cent), transportation equipment (19.7 per cent), rubber (16.7 per cent), chemicals (16.4 per cent), textiles (15.0 per cent), clothing and apparels (14.9 per cent), metal (13.3 per cent) and leather (13.2 per cent). The relatively slower growth sectors were as follows: petroleum and coal (7.2 per cent), furniture (8.5 per cent), food (8.7 per cent) and beverages (8.8 per cent).

(3) Compared with the growth rates of real output (see column 1, Table 1), the growth rates of real value added were smaller in most of the manufacturing sectors. For instance, the manufacturing sector as a whole grew by 12.78 per cent per annum in terms of real value added during 1961-1981, while it increased by 14.24 per cent yearly in terms of real output.

(4) After the 1973 Oil Shock, the growth in real value added decelerated in most sectors, when the growth rate of the Post-Oil-Shock period (1973-1981) and that of the Pre-Oil-Shock period (1961-1973) were compared. The exceptions to this were the construction, food, leather and furniture sectors.

The Growth of Factor Inputs

The growth of factor inputs by sector during 1961-1981 is tabulated in Table 2. From Table 2 we arrive at the following conclusions:

(1) Among the 25 sectors, basic metal had the highest rate of growth in capital input — 29.27 per cent increase per annum during 1961-1981. It was followed by petroleum and coal products (22.57 per cent), mining (21.05 per cent), transportation equipment (19.75 per cent), furniture (16.90 per cent), utilities (16.55 per cent) and transportation and communications (14.24 per cent).

(2) With respect to labour input, the electrical machinery industry registered a growth rate of 14.25 per cent per annum, the highest of all sectors. Next came chemicals (9.79 per cent), metal products (9.26 per cent), construction (8.70 per cent), rubber products (8.29 per cent), miscellaneous manufacturing (8.02 per cent), machinery (7.69 per cent) and basic metal (7.47 per cent).

(3) As for the growth of energy input, leather (24.78 per cent), electrical machinery (19.67 per cent), rubber (18.83 per cent), metal products (15.68 per cent), wood and bamboo (14.83 per cent), furniture (14.83 per cent), transportation and communications (14.37 per cent) were among the highest growth sectors.

(4) For intermediate input, with the exception of construction (13.45 per cent), all of the sectors with two-digit growth rates were in manufacturing. Among the high growth sectors were miscellaneous manufacturing (37.54 per cent), chemicals (30.75 per cent), electrical machinery (23.99 per cent), clothing and apparels (23.76 per cent), printing (20.12 per cent) and wood products (20.06 per cent).

(5) In most sectors, capital and intermediate inputs took the lead in growth rate, while the labour and energy inputs were the laggards.

(6) Compared with the Pre-Oil-Shock period (1961-1973), the growth rates of energy, labour and intermediate inputs generally dropped during the Post-Oil-Shock period (1973-1981). Con-

versely, the growth rate of capital sped up in most of the sectors between the two periods.

Table 2 The growth of factor input by sector, 1961-1981 (%)

Industry	Capital input growth			Labour input growth		
	1961-81	1961-73	1973-81	1961-81	1961-73	1973-81
Agriculture	2.47	2.70	2.12	-1.71	-0.90	-2.93
Mining	21.05	24.21	16.31	1.17	2.85	1.36
Manufacturing	8.79	7.52	10.70	6.92	8.01	5.27
Food	6.86	6.29	7.73	2.42	3.49	0.81
Beverages	5.13	4.86	5.53	3.35	2.64	4.43
Textiles	12.96	14.53	10.59	6.42	10.95	-0.38
Clothing	5.11	7.07	2.18	6.41	7.60	4.62
Leather	8.29	7.46	9.52	3.02	0.86	6.27
Wood	5.75	5.37	6.32	4.46	6.68	1.12
Furniture	16.90	13.95	21.31	4.46	6.68	1.12
Paper	8.55	7.06	10.78	4.95	4.60	5.47
Printing	6.38	6.99	5.48	4.95	4.60	5.47
Chemicals	7.91	6.86	9.48	9.79	11.16	7.73
Rubber	12.25	13.51	10.37	8.29	8.03	8.66
Pet. and coal	22.57	22.94	22.01	5.59	7.21	3.15
Non-metallic	7.93	8.38	7.26	6.81	6.33	7.52
Basic metal	29.27	17.71	46.61	7.47	7.29	7.74
Metal prod.	7.13	6.83	7.58	9.26	9.28	9.24
Machinery	9.95	8.53	12.08	7.69	8.46	6.53
Elec. mach.	11.00	11.47	10.30	14.25	17.32	9.64
Trsp. eqpt.	19.75	21.80	16.69	6.10	5.58	6.88
Misc. mfg.	10.17	6.88	15.10	8.02	8.88	6.74
Utilities	16.55	12.59	22.50	4.53	4.27	4.91
Construction	12.83	9.00	18.57	8.70	7.93	9.84
Trsp. comm.	14.24	14.73	13.52	6.93	9.74	2.72
Services	4.30	3.01	6.23	5.18	5.72	4.38

Table 2 (Continued)

Industry	Intermediate input growth			Energy input growth		
	1961-81	1961-73	1973-81	1961-81	1961-73	1973-81
Agriculture	3.98	4.88	2.61	8.05	10.06	5.02
Mining	6.77	7.11	6.26	5.34	5.91	4.49
Manufacturing	14.69	19.21	7.91	10.03	12.35	6.56
Food	10.10	15.04	2.69	8.28	11.94	2.79
Beverages	12.76	17.37	5.84	8.28	11.94	2.79
Textiles	11.67	18.24	1.81	14.46	19.53	6.87
Clothing	23.76	34.36	7.84	13.17	18.84	4.67
Leather	8.56	19.54	-7.90	24.78	29.70	17.39
Wood	20.06	15.04	27.60	14.83	20.61	6.16
Furniture	5.77	14.11	-6.74	14.83	20.61	6.16
Paper	14.18	14.04	14.39	8.85	10.49	6.39
Printing	20.12	24.07	14.19	7.81	8.05	7.45
Chemicals	30.75	25.46	38.69	10.01	12.57	6.17
Rubber	6.59	17.12	-9.22	18.83	24.27	10.67
Pet. and coal	14.89	21.45	5.05	11.07	11.21	10.87
Non-metallic	14.67	10.42	21.04	9.35	10.15	8.16
Basic metal	18.14	24.34	8.84	3.53	8.52	-3.96
Metal prod.	16.52	17.81	14.59	15.68	17.24	13.33
Machinery	17.24	22.86	8.81	13.81	13.94	13.63
Elec. mach.	23.99	35.81	6.26	19.67	26.58	9.30
Trsp. eqpt.	19.73	23.22	14.49	14.10	18.83	7.01
Misc. mfg.	37.54	51.85	16.07	1.23	5.26	-4.81
Utilities	12.92	16.85	7.03	12.98	19.29	3.51
Construction	13.45	15.24	10.76	12.88	10.15	16.97
Trsp. comm.	6.58	7.50	5.21	14.37	16.74	10.81
Services	9.26	7.88	11.32	6.39	7.65	4.51

The Growth of the Total Factor Productivity (TFP)

Based on Equation (13), the average rate of technical change (or of TFP change) during 1961-1981 is presented in column 1, Table 3. The following important conclusions emerge:

(1) The rubber product sector enjoyed the highest TFP growth — 8.84 per cent per annum during 1961-1981. Next to it was electrical machinery (7.26 per cent). This was followed by miscellaneous manufacturing (6.64 per cent), leather (5.10 per cent), textiles (3.73 per cent), transportation equipment (3.69 per cent). All of these were in manufacturing. Outside manufacturing, the best performer was the service sector (3.12 per cent).

(2) The lagging sectors in terms of TFP growth included mining (-1.90 per cent), utilities (-1.60 per cent) and some manufacturing such as, wood (-7.75 per cent), printing (-6.53 per cent), chemicals (-3.81 per cent), petroleum and coal products (-2.07 per cent), basic metal (-1.43 per cent), paper (-0.91 per cent) and beverages (-0.51 per cent). Most of them were either energy industries or energy-intensive industries.

(3) Compared with the Pre-Oil-Shock period (1961-1973), the TFP growth rate fell in 12 sectors, while it rose in 13 sectors. The notable drop in the TFP growth rate of chemicals and wood after the 1973-Oil-Shock could be attributed to the price hike of their intermediate inputs.

Table 3 The growth of total factor productivity by industry, 1961-1981 (%)

Industry	Output TFP growth			Value added TFP growth		
	1961-81	1961-73	1973-81	1961-81	1961-73	1973-81
Agriculture	1.19	0.87	1.67	3.34	2.82	4.04
Mining	-1.90	-1.77	-2.10	-0.98	1.24	-4.31
Manufacturing	1.70	1.21	2.44	4.83	7.37	1.03
Food	3.38	1.65	5.97	4.47	0.78	1.00
Beverages	-0.51	-0.49	-0.54	4.67	7.05	1.10
Textiles	3.73	2.55	5.50	6.88	6.96	6.76
Clothing	2.28	0.08	5.58	9.09	9.31	8.76
Leather	5.10	-3.19	17.53	8.12	9.22	6.47
Wood	-7.75	3.82	-25.09	0.67	7.67	-9.82
Furniture	1.76	-2.83	8.64	-1.81	-0.82	-3.29
Paper	-0.91	0.00	-2.29	3.27	5.16	0.42
Printing	-6.53	-6.35	-6.80	3.77	5.81	0.73
Chemicals	-3.81	4.55	-16.36	8.23	13.95	-0.35
Rubber	8.84	6.80	11.90	6.85	12.46	-1.58
Pet. and coal	-2.07	-2.03	-2.14	-9.77	-3.03	-19.87
Non-metallic	1.26	3.01	-1.36	2.65	4.45	-0.05
Basic metal	-1.43	-4.90	3.76	-2.61	2.66	-10.54
Metal prod.	0.90	2.38	-1.32	4.82	8.76	-1.07
Machinery	0.20	-0.39	1.08	3.62	5.89	0.22
Elec. mach.	7.26	9.14	4.45	12.86	20.68	1.13
Trsp. eqpt.	3.69	6.27	-0.18	7.66	12.44	0.50
Misc. mfg.	6.64	7.64	5.15	11.92	14.37	8.25
Utilities	-1.61	-2.31	-0.57	-4.70	-0.84	-10.49
Construction	0.46	-0.44	1.81	2.22	1.84	2.80
Trsp. comm.	1.62	1.61	1.65	1.51	1.92	0.89
Services	3.12	5.17	0.04	5.10	7.48	1.54

Growth of TFP of Value Added

Similar to the measurement of the growth of TFP of real total output, the total factor productivity of value added can be calculated using the following equations:

$$\overline{R}_T^V = [lnV(T) - ln\overline{V}(T-1)] - S_K^V [lnK(T) - lnK(T-1)] - \overline{S}_L^V [lnL(T) - lnL(T-1)] \quad (38)$$

where

$$\overline{R}_T^V = \frac{1}{2} [R_T^V(T) + R_T^V(T-1)] \quad (39)$$

$$\overline{S}_K^V = \frac{1}{2} [S_K^V(T) + S_K^V(T-1)] \quad (40)$$

$$\overline{S}_L^V = \frac{1}{2} [S_L^V(T) + S_L^V(T-1)]. \quad (41)$$

Equation (38) implies that the average growth rate of TFP of value added of time T and time T–1 can be measured as the difference between successive logarithms of real value added less a weighted average of the differences between the successive logarithms of capital and labour inputs with weights given by average value shares.

Based on Equation (38), the sectoral growth rate of TFP of real total value added during 1961-1981 is tabulated in Table 3. From Table 3, we conclude:

(1) With an annual growth rate of 12.8 per cent, electrical machinery was the fastest growth sector in the TFP growth in terms of real value added during 1961-1981. It was followed by miscellaneous manufacturing (11.92 per cent), clothing and apparels (9.09 per cent), chemicals (8.23 per cent), leather (8.12 per cent), transportation equipment (7.66 per cent), textiles (6.88 per cent), rubber (6.85 per cent) and services (5.10 per cent).

(2) The laggards were the following: petroleum and coal (-9.77 per cent), utilities (-4.70 per cent), basic metal (-2.61 per cent), furniture (-1.81 per cent) and mining (-0.98 per cent).

(3) After the 1973-Oil-Shock, except for agriculture and the food manufacturing sectors, the growth rates of TFP of value added dropped in all sectors when the Pre-Oil-Shock period and the Post-Oil-Shock periods were compared. In contrast, the tendency of the sectoral growth rates of TFP by total value was inconclusive, since the sectoral growth rate of TFP of total output decreased in 12 sectors, while it increased in 13 sectors.

In addition, the growth rates of sectoral TFP of value added were generally greater than the growth rates of sectoral TFP of total output in most of the sectors, with the exception of furniture and such energy-intensive industries as petroleum and coal products, basic metal, rubber, utilities and transportation.

Sources of Growth in Real Output and Value Added

From the supply side, contributions to the growth of sectoral real output and value added include the increase of capital, labour, energy, and intermediate inputs and technical change, or change of total factor productivity.

Sources of Growth in Real Output

Dividing all items in Equation (13) by the growth rate of real total output (lnQ(T) – lnQ(T–1)), we can measure the relative factor contribution ratios which attribute the contribution of total output growth to the growth in factor inputs and total factor productivity.

The relative factor contribution ratios during 1961-1981 are tabulated in Table 4. From Table 4, the following important conclusions can be drawn:

(1) The greatest relative contribution ratios of TFP can be found in the following sectors: rubber (52.31 per cent), leather (39.7 per cent), agriculture (37.8 per cent), services (33.5 per cent),

miscellaneous manufacturing (30.15 per cent), food (27.77 per cent) and electrical machinery (26.77 per cent).

(2) Compared with the Pre-Oil-Shock period, the relative contribution ratios of TFP increased in most of the sectors (15 out of 25 cases) during the Post-Oil-Shock period.

(3) During 1961 to 1981, the intermediate inputs had the greatest relative contribution ratio (71.6 per cent) toward the real output growth in the manufacturing sector as a whole. It was followed by TFP (11.9 per cent), capital input (6.98 per cent), labour input (6.38 per cent) and energy input (3.10 per cent).

(4) It is to be noted that the relative contribution ratio of capital dominated that of labour not only in the manufacturing sector as a whole but also in all of the non-manufacturing sectors except construction.

(5) Again, compared with the Pre-Oil-Shock period (1961-1973) the relative contribution ratios of capital and labour toward real output growth rose, while energy and intermediate inputs dropped in most of the sectors during the Post-Oil-Shock period (1973-1981).

Table 4 The relative contribution ratio of inputs by industry, 1961-1981 (%)

Industry	Capital			Labour		
	1961-81	1961-73	1973-81	1961-81	1961-73	1973-81
Agriculture	18.08	18.49	17.06	-18.31	-6.79	-46.56
Mining	79.69	105.24	53.90	-26.78	-73.00	19.87
Manufacturing	6.98	5.57	10.47	6.38	6.37	6.41
Food	3.07	2.78	3.77	1.87	2.39	0.59
Beverages	5.75	4.11	12.00	6.18	3.96	14.62
Textiles	3.97	3.55	5.65	5.51	7.16	0.10
Clothing	2.26	2.62	1.28	7.11	6.88	7.72
Leather	7.04	7.53	6.46	4.57	1.39	8.41
Wood	11.39	5.07	-26.39	10.93	8.71	-2.38
Furniture	33.66	22.62	50.18	10.95	17.36	1.34
Paper	10.74	8.49	14.73	5.19	4.61	6.22
Printing	6.04	4.10	14.49	13.46	9.16	32.16
Chemicals	6.66	5.81	9.07	6.31	6.15	6.77
Rubber	6.59	5.47	10.77	8.62	6.20	17.70
Pet. and coal	21.15	20.43	25.92	2.60	2.23	5.05
Non-metallic	8.59	8.81	8.25	11.35	11.41	11.26
Basic metal	7.77	3.86	15.03	3.67	3.86	3.32
Metal prod.	6.37	6.03	7.10	11.86	11.05	13.64
Machinery	10.00	8.31	14.42	9.03	8.09	11.49
Elec. mach.	6.00	4.85	11.49	7.66	6.91	11.24
Trsp. eqpt.	12.49	12.59	12.19	4.16	3.04	7.50
Misc. mfg.	6.97	3.96	12.84	9.60	10.38	8.06
Utilities	33.72	26.00	54.83	2.94	2.42	4.36
Construction	9.04	5.05	14.52	18.88	18.71	19.11
Trsp. comm.	34.83	31.03	42.74	19.01	23.15	10.39
Services	18.04	11.41	32.56	14.97	13.76	17.61

Table 4 (Continued)

Industry	Energy			Intermediate inputs		
	1961-81	1961-73	1973-81	1961-81	1961-73	1973-81
Agriculture	4.75	4.85	4.51	57.73	60.14	51.85
Mining	42.95	65.85	19.83	92.78	100.60	84.89
Manufacturing	3.10	3.34	2.51	71.62	77.57	56.74
Food	0.67	0.84	0.25	66.62	82.62	26.83
Beverages	2.49	2.80	1.31	91.13	93.15	83.34
Textiles	1.92	1.74	2.64	63.44	74.62	19.16
Clothing	1.45	1.64	0.92	76.84	88.51	44.51
Leather	1.94	2.58	1.16	46.75	115.82	-36.32
Wood	4.18	2.69	-4.70	174.38	58.70	-516.75
Furniture	1.12	1.07	1.20	35.43	89.18	-45.00
Paper	6.63	7.36	5.34	85.79	79.55	96.83
Printing	0.81	0.40	2.62	154.14	139.78	216.47
Chemicals	4.38	4.81	3.15	102.99	63.50	215.09
Rubber	2.63	2.06	4.77	29.85	55.69	-67.08
Pet. and coal	7.68	6.86	13.01	85.26	81.79	108.10
Non-metallic	20.29	21.90	17.70	48.97	32.79	74.83
Basic metal	6.81	13.04	-4.75	91.93	111.16	56.25
Metal prod.	4.99	4.20	6.74	70.70	64.59	84.06
Machinery	2.01	1.53	3.27	77.57	84.35	59.74
Elec. mach.	1.03	1.02	1.06	58.54	62.76	38.41
Trsp. eqpt.	2.09	2.48	0.95	63.72	57.96	80.81
Misc. mfg.	1.64	2.66	-0.37	51.65	51.56	51.83
Utilities	47.04	55.23	24.55	31.15	33.68	24.17
Construction	1.06	0.85	1.36	67.38	79.10	51.21
Trsp. comm.	12.34	9.61	18.02	19.38	23.50	10.80
Services	0.69	0.69	0.71	32.79	25.58	48.60

Table 4 (Continued)

Industry	Total factor productivity		
	1961-81	1961-73	1973-81
Agriculture	37.75	23.32	73.14
Mining	-88.64	-98.70	-78.49
Manufacturing	11.92	7.15	23.87
Food	27.77	11.37	68.56
Beverages	-5.55	-4.02	-11.27
Textiles	25.16	12.93	72.45
Clothing	12.34	0.35	45.57
Leather	39.70	-27.32	120.28
Wood	-100.88	24.84	650.23
Furniture	18.84	-30.24	92.28
Paper	-8.35	0.00	-23.12
Printing	-74.46	-53.44	-165.73
Chemicals	-26.34	19.73	-134.09
Rubber	52.31	30.58	133.85
Pet. and coal	-16.69	-11.30	-52.08
Non-metallic	10.80	25.09	-12.04
Basic metal	-10.18	-31.92	30.15
Metal prod.	6.08	14.13	-11.54
Machinery	1.39	-2.29	11.07
Elec. mach.	26.77	24.46	37.80
Trsp. eqpt.	17.54	23.93	-1.45
Misc. mfg.	30.15	31.43	27.63
Utilities	-14.85	-17.33	-7.91
Construction	3.64	-3.71	13.80
Trsp. comm.	14.44	12.71	18.05
Services	33.51	48.55	0.52

Sources of Growth in Real Value Added Growth

Similarly, dividing all items in Equation (38) with the growth rate of real value added (lnV(T) – lnV(T–1)), we can measure the relative factor contribution ratios which allocate the contribution of real value added growth to the growth in factor inputs and TFP of real value added.

Table 5 gives the estimated results of the relative factor contribution ratio toward the growth of real value added during the period of 1961 to 1981. From Table 5, the following conclusions emerge:

(1) The greatest relative contribution ratio of TFP was found in agriculture (100.42 per cent), construction (67.96 per cent), leather (61.64 per cent), clothing and apparels (60.97 per cent), miscellaneous manufacturing (56.82 per cent), beverages (53.39 per cent), services (52.34 per cent), food (51.62 per cent), electrical machinery (50.67 per cent) and chemicals (50.16 per cent).

(2) The laggards of the relative contribution ratio of TFP included furniture and the following energy-intensive industries: petroleum and coal products, utilities, mining and basic metal.

(3) In most of the sectors (16 out of 25 cases), capital led labour in the relative contribution ratio during 1961 to 1981.

(4) Compared with the Pre-Oil-Shock period (1961-1973), the relative contribution ratio of TFP (value added) declined in most of the sectors (17 out of 25 cases) during the Post-Oil-Shock period (1973-1981), while the relative contribution ratio of capital rose in most of the sectors (18 out of 25 sectors). The trend of the relative contribution ratio of labour (with increase in 13 sectors and decrease in 12 sectors) was inconclusive.

(5) In the manufacturing sector as a whole, the largest contribution toward the growth of the real value added came from the growth of TFP, 38.53 per cent. It was then followed by capital (32.35 per cent) and labour (29.12 per cent).

Table 5 The relative factor contribution ratio toward value added growth, 1961-1981 (%)

Industry	Capital input			Labour input		
	1961-81	1961-73	1973-81	1961-81	1961-73	1973-81
Agriculture	32.82	35.66	27.08	-33.24	-13.11	-73.93
Mining	251.89	151.97	-2668.33	-76.57	-106.99	-965.61
Manufacturing	32.35	23.72	54.49	29.12	27.52	33.31
Food	30.02	43.00	21.88	18.36	42.68	3.52
Beverages	21.80	15.88	36.85	24.81	16.75	45.31
Textiles	22.96	20.85	29.49	31.14	42.32	-3.54
Clothing	7.39	9.00	4.20	31.64	34.54	25.93
Leather	22.97	23.31	22.51	15.39	3.84	31.11
Wood	46.46	15.99	-56.54	41.81	27.48	-6.63
Furniture	90.70	61.68	133.32	30.56	48.05	4.87
Paper	45.70	34.45	66.95	22.02	18.72	28.26
Printing	17.91	14.49	26.95	40.35	32.41	61.35
Chemicals	25.83	18.34	60.50	24.02	19.63	44.31
Rubber	25.70	21.20	45.40	33.30	23.76	74.96
Pet. and coal	213.60	107.85	-237.34	22.89	11.62	-25.14
Non-metallic	31.78	26.65	43.67	41.20	34.40	56.97
Basic metal	82.71	39.14	154.06	38.39	40.05	35.68
Metal prod.	21.89	17.11	37.68	41.78	31.34	76.27
Machinery	37.08	29.28	55.47	33.10	29.31	42.04
Elec. mach.	21.96	16.96	45.29	27.37	23.69	44.54
Trsp. eqpt.	44.70	40.74	57.93	16.37	10.02	37.61
Misc. mfg.	18.53	9.71	34.49	24.65	26.47	21.37
Utilities	140.77	99.77	225.60	11.68	8.64	17.97
Construction	26.54	17.90	35.27	5.50	63.86	46.03
Trsp. comm.	55.39	48.56	72.26	31.88	37.77	17.35
Services	25.83	15.85	50.50	21.84	19.51	27.60

Table 5 (Continued)

Industry	Total factor productivity		
	1961-81	1961-73	1973-81
Agriculture	100.42	77.45	146.85
Mining	-75.32	55.02	3733.94
Manufacturing	38.53	48.76	11.90
Food	51.62	14.32	74.60
Beverages	53.39	67.37	17.84
Textiles	45.90	36.83	74.05
Clothing	60.97	56.46	69.87
Leather	61.64	72.85	46.38
Wood	11.73	56.53	163.17
Furniture	-21.26	-9.73	-38.19
Paper	32.29	46.83	4.79
Printing	41.74	53.10	11.70
Chemicals	50.16	62.03	-4.81
Rubber	41.00	55.04	-20.35
Pet. and coal	-136.49	-19.47	362.48
Non-metallic	27.02	38.95	-0.64
Basic metal	-21.10	20.81	-89.74
Metal prod.	36.33	51.55	-13.95
Machinery	29.83	41.42	2.48
Elec. mach.	50.67	59.35	10.17
Trsp. eqpt.	38.93	49.24	4.46
Misc. mfg.	56.82	63.82	44.14
Utilities	-52.45	-8.41	-143.57
Construction	67.96	18.24	18.70
Trsp. comm.	12.73	13.67	10.39
Services	52.34	64.65	21.90

Sources of Growth in Total Factor Productivity

To analyse the sources of growth in TFP (total output), we rearrange Equation (13) as follows:

$$\begin{aligned}\overline{R}_T = \overline{S}_K\,&[\ln(Q(T)/K(T)) - \ln(Q(T-1)/K(T-1))]\\ &+ \overline{S}_L\,[\ln(Q(T)/L(T)) - \ln(Q(T-1)/L(T-1))]\\ &+ \overline{S}_E\,[\ln(Q(T)/E(T)) - \ln(Q(T-1)/E(T-1))]\\ &+ \overline{S}_M\,[\ln(Q(T)/M(T)) - \ln(Q(T-1)/M(T-1))]. \qquad (42)\end{aligned}$$

Equation (42) implies that the average growth rate of total factor productivity of total output $\overline{R}_T$ is the weighted average of the growth rate of capital productivity $\ln(Q(T)/K(T)) - \ln(Q(T-1)/K(T-1))$, the growth rate of labour productivity $\ln(Q(T)/L(T)) - \ln(Q(T-1)/L(T-1))$, the growth rate of energy productivity $\ln(Q(T)/E(T)) - \ln(Q(T-1)/E(T-1))$ and intermediate input productivity $\ln(Q(T)/M(T)) - \ln(Q(T-1)/M(T-1))$. Since $\overline{S}_K$, $\overline{S}_L$, $\overline{S}_E$ and $\overline{S}_M$, are non-negative, the greater the growth of the factor productivities, the greater will be the growth of total factor productivity.

During 1961 to 1981, the serial correlation between the growth rates of various factor productivities and total factor productivity in the 25 sectors is as follows: capital productivity, 0.49; labour productivity, 0.57; energy productivity, 0.19; intermediate input productivity, 0.66. Except for energy productivity, all of the serial correlation coefficients between various factor productivities and TFP are significantly different from 0 at a 0.05 significance level. This implies that the increase of the intermediate input productivity was the number one contributor of the TFP growth in Taiwan's average industry. It was followed by the growth in productivity of labour and capital. In contrast, the growth of energy was the least relevant factor toward the TFP growth in average industry.

It is worth noting that, if we decompose the whole period into two subperiods, the serial correlation coefficient between the growth of energy productivity and the growth of TFP, γ_{ET}, in the Pre-Oil-Shock period (1961-1973) is estimated to be 0.41, and its Z value is significantly differently from zero at 0.05 significant level. Nonetheless, the γ_{ET} in the Post-Oil-Shock period (1973-1981) is 0.21 and is still insignificantly different from zero.

Growth of Partial Factor Productivity

Partial factor productivity is defined as the output/input ratio. The productivity growth of capital, labour, energy and intermediate inputs by sector during 1961 to 1981 is presented in Table 6.

Growth of Capital Productivity

Table 6 gives the capital productivity by sector during 1961 to 1981. The following conclusions can be drawn:

(1) The electrical machinery, with a 16.1 per cent annual growth rate led all sectors in the growth of capital productivity during 1961 to 1981. It was then followed by clothing and apparels (13.4 per cent), miscellaneous manufacturing (11.9 per cent), chemicals (10.8 per cent), metal product (7.6 per cent) and food (5.3 per cent). All of the sectors mentioned above are in the manufacturing sector. As to non-manufacturing sectors, the ranking of the growth of capital productivity is as follows: services (2.9 per cent), agriculture (0.7 per cent), construction (-0.3 per cent), transportation and communications (-3.0 per cent), utilities (-5.6 per cent) and mining (-18.9 per cent).

Table 6 The growth of partial factor productivity by industry, 1961-1981 (%)

Industry	Capital productivity growth			Labour productivity growth		
	1961-81	1961-73	1973-81	1961-81	1961-73	1973-81
Agriculture	0.67	1.02	0.15	4.86	4.62	5.20
Mining	-18.90	-22.41	-13.64	3.31	4.65	1.31
Manufacturing	5.46	9.42	-0.49	7.33	8.92	4.94
Food	5.30	8.18	0.97	9.74	10.98	7.89
Beverages	4.21	7.47	-0.67	5.98	9.69	0.43
Textiles	1.88	5.21	-3.12	8.42	8.79	7.86
Clothing	13.37	15.57	10.07	12.08	15.04	7.63
Leather	4.55	4.22	5.05	9.81	10.82	8.30
Wood	1.93	10.00	-10.18	3.22	8.69	-4.98
Furniture	-7.54	-4.61	-11.95	4.90	2.67	8.24
Paper	2.40	4.60	-0.90	6.00	7.06	4.41
Printing	2.39	4.90	-1.37	3.82	7.29	-1.37
Chemicals	10.82	16.22	2.72	8.94	11.92	4.47
Rubber	4.64	8.72	-1.48	8.61	14.20	0.23
Pet. and coal	-10.14	-4.97	-17.91	6.84	10.76	0.95
Non-metallic	3.77	3.61	4.00	4.89	5.66	3.73
Basic metal	-15.05	-2.31	-34.16	6.75	8.12	4.71
Metal prod.	7.61	10.04	3.95	5.47	7.59	2.29
Machinery	4.25	8.61	-2.30	6.51	8.68	3.25
Elec. mach.	16.12	25.89	1.47	12.88	20.04	2.14
Trsp. eqpt.	1.28	4.41	-3.41	14.93	20.63	6.39
Misc. mfg.	11.87	17.44	3.53	14.02	15.43	11.89
Utilities	-5.62	0.76	-15.19	6.41	9.08	2.40
Construction	-0.34	3.06	-5.43	3.80	4.13	3.30
Trsp. comm.	-3.01	-2.08	-4.40	4.30	2.91	6.39
Services	2.91	3.00	2.77	0.04	2.76	-4.04

Table 6 (Continued)

Industry	Energy productivity growth			Intermediate productivity growth		
	1961-81	1961-73	1973-81	1961-81	1961-73	1973-81
Agriculture	-1.90	-6.34	-2.74	-0.83	-1.16	-0.33
Mining	-3.20	-4.11	-1.82	-4.62	-5.31	-3.59
Manufacturing	4.21	4.58	3.66	-0.45	-2.28	2.31
Food	3.87	2.52	5.91	2.06	-0.58	6.02
Beverages	1.05	0.38	2.06	-3.42	-5.05	-0.98
Textiles	0.37	0.22	0.60	3.17	1.50	5.66
Clothing	5.32	3.80	7.59	-5.27	-11.72	4.41
Leather	-11.94	-18.01	-2.82	4.28	-7.85	22.47
Wood	-7.15	-5.24	-10.02	-12.39	0.33	-31.46
Furniture	-5.48	-11.26	3.20	3.58	-4.77	16.10
Paper	2.10	1.17	3.49	-3.23	-2.38	-4.51
Printing	0.96	3.84	-3.34	-11.35	-12.19	-10.08
Chemicals	8.72	10.51	6.03	-12.02	-2.38	-26.49
Rubber	-1.94	-2.04	-1.78	10.31	5.11	18.11
Pet. and coal	1.35	6.76	-6.77	-2.47	-3.48	-0.95
Non-metallic	2.34	1.84	3.10	-2.97	1.57	-9.78
Basic metal	10.70	6.88	16.42	-3.92	-8.94	3.61
Metal prod.	-0.95	-0.38	-1.80	-1.79	-0.94	-3.06
Machinery	0.39	3.21	-3.84	-3.04	-5.71	0.98
Elec. mach.	7.46	10.78	2.47	3.14	1.55	5.51
Trsp. eqpt.	6.93	7.38	6.26	1.30	2.98	-1.22
Misc. mfg.	20.81	19.05	23.44	-15.50	-27.54	2.56
Utilities	-2.04	-5.94	3.81	-1.98	-3.50	0.29
Construction	-0.39	1.90	-3.83	-0.96	-3.18	2.38
Trsp. comm.	-3.13	-4.08	-1.70	4.65	5.15	3.90
Services	5.00	7.64	1.05	4.11	4.92	2.90

The Growth of Labour Productivity

The estimated results of sectoral growth in labour productivity during 1961 to 1981 are shown in Table 6, which can be summarized as follows:

(1) The labour productivity of transportation equipment manufacturing grew at a pace of 14.9 per cent per annum in outpacing the other sectors during 1961 to 1981. It was followed by miscellaneous manufacturing (14.0 per cent), electrical machinery (12.9 per cent), clothing and apparels (12.1 per cent), leather (9.8 per cent), food (9.7 per cent), chemicals (8.9 per cent), rubber (8.6 per cent) and textiles (8.4 per cent).

(2) After the 1973 Oil Shock, the growth rate of labour productivity fell in all of the sectors except agriculture, furniture and transportation. However, labour productivity continued to grow in all except the service sector and wood products, printing manufacturing even after the 1973 Oil Shock.

The Growth of Energy Productivity

The growth of sectoral energy productivity is presented in Table 6, from which we conclude as follows:

(1) The miscellaneous manufacturing industry, with a 20.8 per cent annual rate took the lead in the growth of energy productivity among all of the sectors. It was followed by the following manufacturings: basic metal (10.7 per cent), chemicals (8.7 per cent), electrical machinery (7.5 per cent), transportation equipment (6.9 per cent), clothing and apparels (5.3 per cent). The service sector whose energy productivity grew by 5.0 per cent per annum outperformed other non-manufacturing sectors. It is worthy of note that the growth rates of energy productivity in other non-manufacturing sectors were all negative during 1961 to 1981, implying that energy productivity declined in all of the non-manufacturing sectors except the service sector. These sectors included construction (-0.4 per cent), public utilities (-2.0 per cent), transportation and communications (-3.1 per cent), mining (-3.2 per cent) and agriculture (-1.9 per cent).

(2) We found that energy productivity not only increased but also accelerated in the public utilities and the following manufacturing industries: food, beverages, textiles, clothing and apparels, furniture, paper, non-metallic mineral products, basic metal and miscellaneous manufacturing. However, the number of sectors characterized by negative growth rate in energy productivity increased from nine in the Pre-Oil-Shock period (1961-1973) to 11 in the Post-Oil-Shock period (1973-1981). We conclude that the improvement of energy productivity has not successfully taken place in Taiwan's average industries during 1973 to 1981. This could be attributed to the cheap energy pricing policy adopted by the government during the Post-Oil-Shock period of 1973 to 1981 and the implementation of the "Ten Big Projects" at the same time.

The Growth of Intermediate Input Productivity

The estimated growth rates of intermediate input productivity are tabulated in Table 6. From Table 6, the following conclusions emerge:

(1) The growth rate of intermediate input productivity was negative in 16 out of 25 sectors from 1961 to 1981. The sectors with positive growth rates of intermediate input productivity included (in a descending order): rubber products (10.3 per cent), transportation and communications (4.65 per cent), leather (4.28 per cent), services (4.1 per cent), furniture (3.6 per cent), textiles (3.2 per cent), electrical machinery (3.1 per cent), food (2.1 per cent) and transportation equipment (1.3 per cent).

(2) However, the number of industries characterized by positive growth rates of intermediate input productivity increased from eight in the period during 1961-1973 to 14 in the period 1973 to 1981, implying that the intermediate input productivity significantly improved in Taiwan's industry after the 1973 Oil Shock. The major contributor to this change was the general price hike in intermediate inputs and the material-saving technology developed after 1973.

(3) Compared with the Pre-Oil-Shock period (1961-1973), the industries characterized by accelerating positive intermediate input productivity growth during the Post-Oil-Shock period (1973-1981) included utilities, construction, and the following manufacturing sectors: food, textiles, clothing and apparels, leather, furniture, rubber, basic metal, machinery, electrical machinery and miscellaneous manufacturing.

International Comparison among Taiwan, U.S. and Japan

We employ the results of the Jorgenson, Kuroda and Nishimizu (1986) to conduct an international comparison among Taiwan, U.S. and Japan during 1961-1981. The international comparison of growth in output, inputs and total factor productivity is tabulated in Table 7. From Table 7, the following important conclusions can be drawn:

(1) Except for the mining sector, Taiwan had the greatest growth rate among the three countries in industry real output growth. This could be attributed to Taiwan's higher growth rates of inputs and total factor productivity in average industries than that of the U.S. and Japan.

(2) Taiwan outpaced the U.S. and Japan in the growth of labour input in 19 out of 22 industries. In the growth of intermediate inputs, Taiwan surpassed the other two countries in 20 sectors; while, it occupied a leveling position in the growth of capital input in 10 sectors, compared to 12 sectors of Japan and one sector of the U.S.

(3) On the average, the relative contribution of all inputs toward the growth of real output was greater than that of the total factor productivity in Taiwan. For instance, the relative contribution rates of factor inputs and TFP toward the growth of real total output were 88 per cent and 12 per cent respectively in Taiwan's manufacturing sectors as a whole.

(4) As to the growth of TFP, the U.S. merely led Japan and Taiwan in two sectors, namely, the agriculture and printing sectors. Japan led in eight sectors, i.e., mining, utilities, transportation, and the following manufacturing sectors: wood, paper, chemicals, basic metal and machinery. Taiwan took the lead in the

following 12 sectors: food, textiles, leather, furniture, rubber, petroleum and coal, non-metallic product, electrical machinery, transportation equipment, miscellaneous manufacturing, construction and services.

Table 7 Industry-level international comparison of growth in total output, input and TFP, 1961-1981 (%)

Industry	Total output growth			Output TFP growth		
	Taiwan	U.S.	Japan	Taiwan	U.S.	Japan
Agriculture	3.15	2.21	1.31	1.19	1.32	-0.78
Mining	2.15	2.11	3.43	-1.90	-3.02	2.17
Food	12.16	2.58	5.89	3.38	0.05	-1.23
Textiles	14.84	3.93	3.44	3.73	2.12	0.29
Leather	12.84	-0.53	7.30	5.10	-0.15	0.67
Wood	7.68	3.27	5.78	-7.75	-0.51	1.88
Furniture	9.35	3.94	8.67	1.76	0.35	1.01
Paper	10.95	3.80	7.61	-0.91	0.47	0.88
Printing	8.77	2.75	6.56	-6.53	0.98	-0.08
Chemicals	18.73	5.35	10.16	-3.81	0.91	2.49
Rubber	16.89	5.32	7.02	8.84	0.86	0.59
Pet. and coal	12.42	3.63	10.53	-2.07	-3.10	-3.16
Non-metallic	11.70	2.83	9.30	1.26	0.22	1.20
Basic metal	14.22	2.48	9.07	-1.43	-0.44	0.90
Machinery	14.20	5.19	10.16	0.20	0.72	1.29
Elec. mach.	27.12	5.75	13.28	7.26	1.99	3.28
Trsp. eqpt.	21.03	3.14	9.36	3.69	0.44	3.07
Misc. mfg.	22.04	2.63	12.77	6.64	-0.25	2.89
Utilities	10.93	4.51	8.86	-1.61	-0.11	0.91
Construction	12.49	1.48	8.09	0.46	-0.74	-1.39
Trsp. comm.	11.24	3.77	8.54	1.62	1.03	2.64
Services	9.30	3.58	8.46	3.12	0.93	0.83

Table 7 (Continued)

Industry	Capital input growth			Labour input growth		
	Taiwan	U.S.	Japan	Taiwan	U.S.	Japan
Agriculture	2.47	3.31	5.54	-1.71	-2.93	-3.33
Mining	21.05	3.92	3.58	-1.17	2.50	-7.47
Food	6.86	3.06	10.61	2.42	0.00	3.67
Textiles	12.96	2.81	5.28	6.42	-0.03	-1.68
Leather	8.29	1.29	9.13	3.02	-1.97	2.25
Wood	5.75	3.01	5.71	4.46	1.14	0.10
Furniture	16.90	4.61	9.25	4.46	1.44	3.12
Paper	8.55	2.64	10.16	4.95	1.11	1.83
Printing	6.38	2.51	8.67	4.95	1.34	2.80
Chemicals	7.91	4.73	10.09	9.79	1.93	1.60
Rubber	12.25	6.09	13.02	8.29	3.66	1.43
Pet. and coal	22.57	2.03	12.44	5.59	0.84	3.44
Non-metallic	7.93	2.66	12.17	6.81	1.15	2.79
Basic metal	29.27	1.45	11.62	7.47	0.76	0.68
Machinery	9.95	4.76	13.16	7.69	3.09	2.73
Elec. mach.	11.00	5.76	12.37	14.25	2.13	4.90
Trsp. eqpt.	19.75	3.33	11.00	6.10	0.92	-0.21
Misc. mfg.	10.17	2.80	14.55	8.02	0.61	3.93
Utilities	16.55	5.41	10.88	4.53	1.73	2.21
Construction	12.83	3.11	13.46	8.70	2.70	6.70
Trsp. comm.	14.24	5.79	7.18	6.93	1.48	3.28
Services	4.30	4.22	10.07	5.18	1.74	5.93

Table 7 (Continued)

Industry	Intermediate input growth		
	Taiwan	U.S.	Japan
Agriculture	3.98	2.32	2.91
Mining	6.77	6.59	4.68
Food	10.10	3.03	6.25
Textiles	11.67	2.44	3.18
Leather	8.56	0.37	7.22
Wood	20.06	5.76	4.77
Furniture	5.77	4.77	9.34
Paper	14.18	4.38	6.73
Printing	20.12	1.97	8.57
Chemicals	30.75	5.24	8.08
Rubber	6.59	4.76	6.61
Pet. and coal	14.89	7.86	14.12
Non-metallic	14.67	3.61	8.66
Basic metal	18.14	3.86	8.20
Machinery	17.24	5.59	9.70
Elec. mach.	23.99	4.67	10.67
Trsp. eqpt.	19.73	3.71	7.46
Misc. mfg.	37.54	4.11	10.86
Utilities	12.92	5.16	9.32
Construction	13.45	1.82	9.66
Trsp. comm.	6.58	2.54	8.74
Services	9.26	3.39	7.16

(5) Compared the growth rate of TFP industry by industry among the three countries, the laggards of the TFP growth in the U.S. were mining, transportation, leather, furniture, non-metallic mineral products, electrical machinery, transportation equipment and miscellaneous manufacturing. The laggards in Japan were agriculture, construction, services, food, textiles, rubber, and petroleum and coal. In Taiwan, the industries included wood, paper, printing, chemicals, basic metal, machinery and utility industries.

V. Conclusion and Suggestions

The objective of this chapter has been to measure the growth of industrial output, inputs and productivity change and to analyse the causes of growth in output and total factor productivity during 1961 to 1981. For this, a translog index, which is theoretically more general than the conventional Cobb-Douglas and CES functions, has been employed in the calculation. In addition, an international comparison among the United States, Japan and Taiwan has been conducted. Finally, policy implications are drawn from the findings.

The main findings and implications are as follows:

(1) Comparing the growth rates of the U.S., Japan and Taiwan, we found that Taiwan had the fastest growth rate in all of the 22 industries except mining during 1961-1981. This could be attributed to Taiwan's higher growth rates of inputs and total factor productivity across industries than that of the U.S. and Japan during the same period.

(2) Compared with the Pre-Oil-Shock period (1961-1973), the growth rates of capital and energy productivities dropped, while the growth rates of labour and intermediate input productivities increased in most of the sectors during the Post-Oil-Shock period (1973-1981).

(3) On the average, the relative contribution of all inputs toward the growth of real output was greater than that of the total factor productivity in Taiwan. For instance, the relative contribu-

tion rates of factor inputs and TFP toward the growth of real total output were 88 per cent and 12 per cent respectively in Taiwan's manufacturing sector as a whole during 1961 to 1981.

(4) The relative contribution ratios of capital and labour toward output growth rose, while that of energy and intermediate inputs declined in most of the sectors during the Post-Oil-Shock period, compared with the Pre-Oil-Shock period.

(5) The growth rates of sectoral TFP of value added were generally greater than the growth rate of sectoral TFP of total output in most of the sectors during 1961 to 1981. For instance, in the manufacturing sector as a whole, the TFP of value added increased by 4.8 per cent per annum during 1961 to 1981, while the TFP of total output grew with a 1.7 per cent clip per annum during the same period. In addition, as compared with the Pre-Oil-Shock period, the relative contribution ratio of TFP toward the output growth increased in most sectors (15 out of 25 cases) during the Post-Oil-Shock period; while, the relative contribution ratio of TFP toward the real value added growth declined in most sectors (17 out of 25 cases) at the same time. Since, theoretically, to measure the TFP with total output is better than with value added, we are convinced that the conventional way of measuring TFP with value added might be misleading.

(6) Compared with the Pre-Oil-Shock period (1961-1973), the growth rates of energy, labour and intermediate inputs generally dropped during the Post-Oil-Shock period (1973-1981). Conversely, the growth rate of capital speeded up in most of the sectors during the same period.

(7) Consequently, capital led labour in the relative contribution ratio toward the growth of both the real total output and real value added during 1961 to 1981 in 16 out of 25 industries. This implies that, in addition to total factor productivity growth, the marked capital growth was one of the key elements which led to the fast economic growth of Taiwan.

Notes

1. According to the *Classified Index of Empirical Research on Taiwan's Economy*, published by the Chinese Economists Association in 1984, papers under items of "productivity" and "technical changes" had exceeded 60.
2. Christensen, Jorgenson and Lau (1971) introduced the translog function which is a much more generalized functional form than the Cobb-Douglas and CES. It is a second order approximation constant elasticity of substitution like the Cobb-Douglas and CES.
3. See Gollop and Jorgenson (1980).
4. See Gollop and Jorgenson (1980). For proof, see Diewert (1976).
5. See Berndt (1980) and Diewert (1976).

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12

Aggregate Productivity Trends of Taiwan

Chin-sheun Ho

I. Introduction

The Republic of China in Taiwan has achieved a very high economic growth rate over the past four decades. In the same period, it has attained price stability, full employment, a surplus of general government budget and trade, and a very equitable income distribution. The per capita GNP in terms of US dollars increased more than 45 times from US$196 in 1952 to US$8,815 in 1991. The compound annual growth rates of both per capita GNP in US dollars and the real GNP were 10.25 per cent and 8.71 per cent. The amount of foreign exchange reserve of the Central Bank reached US$82.405 billion at the end of 1991.

This chapter discusses the factors contributing to the growth of aggregate productivity in Taiwan and the measurement of productivity. In Section II, the one-factor and the two-factor production functions are introduced; both are popular and useful in empirical studies. In Section III, I will discuss the data collection which is very important in my research. Here, I talk a little bit about the sources of data and methods of data compilation in my model. It is easy to get the complete data of national income statistics of Taiwan because the national accounting system has been well established during the last 40 years.

In Section IV, because the empirical results of Taiwan are not all appropriate for the different production function models, the necessary evaluation will help us to explain the productivity performance of Taiwan in the past 40 years. Some policy implications will be presented.

Meanwhile, I will discuss the important factors that improve productivity growth and the unfavourable ones that cause productivity to decline. These unfavourable factors are obstacles that we must overcome in the future. Section V gives some concluding remarks.

II. The Production Function Model

The one-factor aggregate production function is defined as:

$$Y_t = F(X_t), \tag{2.1}$$

where t is year, X_t and Y_t are the "efficiency-equivalent quantities" of output and input respectively of a given time period, t. The productivity of a factor is the ratio of output divided by its input:

$$AP_{xt} = Y_t/X_t. \tag{2.2}$$

Actually, we cannot find the "efficiency-equivalent" quantities. Fortunately, in national income statistics, it is convenient for us to deflate the current values of different years into "constant price values" or "constant values." These data may be in place of the "efficiency-equivalent" quantity.

The input/output ratio is a technical coefficient which is exactly equal to the inverse of average productivity:

$$\begin{aligned} X_{ijt} &= X_{it}/X_{jt} \\ &= 1/AP_{xt} \end{aligned} \tag{2.3}$$

where X_{it} corresponds to Y_t and X_{jt} to X_t.

The input/output coefficient is assumed to be fixed at a given time. Any changes of relative factor price are not considered in the situation of resource allocation.

Next, I define the two-factor production function model as:

$$Y_t = f(X_{1t}, X_{2t}) \tag{2.4}$$

where X_{1t}, X_{2t} and Y_t are the "efficiency-equivalent quantities" of inputs and output respectively. I continue to use the constant price value instead of the "efficient-equivalent quantities." In this model, the average productivity of both factors has the same form as the one-factor model:

$$\begin{aligned} AP_{x1t} &= Y_t/X_{1t} \text{ ... for the factor of } X_{1t} \\ AP_{x2t} &= Y_t/X_{2t} \text{ ... for the factor of } X_{2t}. \end{aligned} \tag{2.5}$$

The total factor productivity is defined as:

$$\begin{aligned} TFP_t &= Y_t/TX_t \\ &= Y_t/(P_{1t}X_{1t} + P_{2t}X_{2t}) \end{aligned} \tag{2.6}$$

where

P_{1t} is the factor price of X_{1t},

P_{2t} is the factor price of X_{2t}.

The growth of total factor productivity is defined as:

$$TFP_t^* = Y_t^* - S_{1t}X_{1t}^* - S_{2t}X_{2t}^* \tag{2.7}$$

where TFP_t^*, Y_t^*, X_{1t}^*, X_{2t}^* are growth rates of TFP_t, Y_t, X_{1t}, X_{2t} respectively; S_{1t} and S_{2t} are factor shares of X_{1t} and X_{2t}. All these data could be changed into the Tornqvist index for empirical research.

The two-factor model could be represented by unrestricted and restricted Cobb-Douglas production functions:

$$LN(Y_t) = A + \alpha LN(X_{1t}) + \beta LN(X_{2t}) + \delta t, \qquad (2.8)$$

where

$\alpha + \beta = 1$ ...... constant returns to scale
$\alpha + \beta > 1$ ...... increasing constant returns to scale
$\alpha + \beta < 1$ ...... decreasing constant returns to scale
δ is the rate of technological progress.

In the case of constant returns to scale, $\beta = 1 - \alpha$ is the factor share of X_{2t}, and α is the factor share of X_{1t} respectively.

The average productivity of each factor is defined as:

$$\begin{aligned} APX_{1t} &= Y_{1t}/X_{1t} \\ &= A(X_{2t}/X_{1t})^{\beta} \exp(\delta_t) \text{ ... for the factor } X_{1t} \end{aligned} \qquad (2.9)$$

$$\begin{aligned} APX_{2t} &= Y_t/X_{2t} \\ &= A(X_{1t}/X_{2t})^{\alpha} \exp(\delta_t) \text{ ... for the factor } X_{2t}. \end{aligned} \qquad (2.10)$$

The growth of total factor productivity is defined as:

$$\begin{aligned} TFP_t^{\cdot} &= Y_t^{\cdot} - S_{1t}X_{1t}^{\cdot} - S_{2t}X_{2t}^{\cdot} \\ &= Y_t^{\cdot} - \alpha X_{1t}^{\cdot} - (1-\alpha)X_{2t}^{\cdot}. \end{aligned} \qquad (2.11)$$

Another form of the two-factor production model is the transcendental logarithmic (translog) functional form. It was introduced by Christensen, Jorgenson and Lau (1973). The translog production function with capital (K) and labour (L) as inputs, assumes the following form:

$$\begin{aligned} LN(Y\varepsilon_t) = {} & LN(Y_o) + \alpha_l LN(L\varepsilon_t) + \beta_k LN(K\varepsilon_t) \\ & + \alpha_{ll}(LN(L\varepsilon_t))^2/2 + \beta_{kk}(LN(K\varepsilon_t))^2/2 \\ & + \beta_{kl}(LN(L\varepsilon_t))(LN(K\varepsilon_t)). \end{aligned} \qquad (2.12)$$

All the "efficiency-equivalent" output and input can be expressed in terms of time and measured quantities of output and inputs:

$$Y\varepsilon_t = A_o \exp(c_o t)Y_t \qquad (2.13)$$

$$L\varepsilon_t = A_l \exp(c_l t)L_t \qquad (2.14)$$

$$K\varepsilon_t = A_k \exp(c_k t)K_t \qquad (2.15)$$

where A_o, A_l, A_k, c_l, and c_k are constants. A_o, A_l, A_k are argumentation level parameters and c_o, c_l and c_k are argumentation rate parameters. By substituting Equations (2.13), (2.14) and (2.15) into (2.12), we obtain the following translog function:

$$\begin{aligned} LN(Y_t) = {} & LN(Y_o) - LN(A_o) + \alpha_l LN(A_l) + \beta_k LN(A_k) \\ & + \beta_{kk}(LN(A_k))^2/2 + \alpha_{ll}(LN(A_l))^2/2 \\ & + \beta_{kl}(LN(A))(LN(A)) \\ & + (\beta_k + \beta_{kk}(LN(A_k))) + \beta_{kl}(LN(A_l))(LN(K_t)) \\ & + (\alpha_l + \alpha_{ll}(LN(A_l))) + \beta_{kl}(LN(A_k))(LN(L_t)) \\ & + \beta_{kk}(LN(K_t))^2/2 + \alpha_{ll}(LN(L_t))^2/2 \\ & + \beta_{kl}(LN(A_k))(LN(L_t)) \\ & + (-c_o + \alpha_l c_l + \beta_k c_k + \beta_{kk}(LN(A_k))c_k + \beta_{kl}LN(A_l))c_k \\ & + \alpha_{ll}(LN(A_l))c_l + \beta_{kl}((LN(A_k))c_l)t \\ & + (\beta_{kk}c_k + \beta_{kl}c_l)(LN(K_t)t) + (\beta_{kl}c_k + \alpha_1 c_l)(LN(L_t))t \\ & + (\beta_{kk}(c_k) + 2\beta_{kl}c_k c_l + \alpha_{ll}(c_l))^2 t^2/2. \end{aligned} \qquad (2.16)$$

It can be simplified as:

$$\begin{aligned} LN(Y_t) = {} & LN(Y_o) + LN(A_o) \\ & + \alpha_l(LN(L_t)) + \beta_k(LN(K_t)) \\ & + \beta_{kk}(LN(K_t))^2/2 + \alpha_{ll}(LN(L_t))^2/2 \\ & + \beta_{kl}(LN(L_t))(LN(K_t)) \\ & + c_o t + (\beta_{kk}c_k + \beta_{kl}c_l)LN(K_t)t \\ & + (\beta_{kl}c_k + \alpha_{ll}c_l)LN(L_t)t \\ & + (\beta_{kk}c_{k2} + 2\beta_{kl}c_l c_k + \alpha_{ll}c_{l2})t^2/2. \end{aligned} \qquad (2.17)$$

We can test if Taiwan's different sectors are identical in α_{ll} and β_{kl}.

In addition to the aggregate production function of Taiwan, we also build the cost share of labour and capital as follows:

$$S_{lt} = \frac{w_t^* L_t}{P_t^* Q_t}$$
$$= \alpha_l + \beta_{kl}LN(K_t) + \alpha_{ll}LN(L_t) + \alpha_{lt}t \qquad (2.18)$$

$$S_{kt} = \frac{r_t^* K_t}{P_t^* Q_t}$$
$$= \beta_k + \beta_{lk}LN(L_t) + \beta_{kk}LN(K_t) + \beta_{kt}t \qquad (2.19)$$

where w_t and r_t are factor price of labour and capital in Taiwan, P_t is the price deflator and Q_t is the real output, respectively.

$$\alpha_l + \beta_k = 1 \qquad (2.20)$$
$$\alpha_{lt} + \beta_{kt} = 0 \qquad (2.21)$$
$$\beta_{kl} = \beta_{lk} \qquad (2.22)$$
$$\alpha_{lk} + \alpha_{ll} = \beta_{kk} + \beta_l = 0. \qquad (2.23)$$

Under the assumption of profit maximization, the estimated parameters in Equations (2.20-2.23) are identical to the corresponding ones in Equation (2.17). These two equations constitute the estimating equations for this study.

III. The Data

In Taiwan, the *National Income Statistics in Taiwan Area* and *Labour Force Survey Statistics in Taiwan Area* both cover the data period from 1951 to 1991, and the *National Wealth Survey in Taiwan*, first published in 1989, gives us very complete and detailed data for empirical study.

Before the detailed data are discussed, I first give a brief summary of the average annual growth rate of real GDP, capital and labour in Table 1.

Table 1 Average annual growth rate of real GDP, real fixed capital stock, investment and employment of labour in Taiwan

	1952-60	1961-70	1971-80	1981-89	1952-89
Real GDP	7.56	9.66	9.83	8.64	9.00
Real fixed					
Capital stock	0.27	0.98	3.58	4.88	2.48
Capital formation	14.68	17.52	14.76	5.40	3.01
Labour employment	2.15	2.81	3.66	2.62	2.85

The data of Taiwan comprise:

1. Real output

The aggregate output of Taiwan's economy is measured by real gross domestic product (GDP) at the 1986 constant prices in *National Income Statistics in Taiwan Area*, published by the Directorate General of Budget, Accounting and Statistics, Executive Yuan, ROC, in 1991.

2. Labour employment

The total labour employment data are taken from the *Labour Force Survey Statistics in Taiwan Area*, published by the Directorate General of Budget, Accounting and Statistics, Executive Yuan, ROC, in 1982 and 1992.

3. Fixed capital stock

The fixed capital stock in 1988 is from the *General Report of Wealth Survey in Taiwan Area*, published by the Directorate General of Budget, Accounting and Statistics, Executive Yuan, ROC, in 1989.

The fixed capital stock of 1952-1989 is estimated by adding or subtracting the real net fixed capital formation (investment) from the fixed capital stock of 1988.

Real net fixed capital formation is obtained from the gross domestic fixed capital formation and depreciation, taken from the *National Income Statistics in Taiwan Area.*

$$K_t = K_{t-1} + I_t - D_t \qquad (3.1)$$

where

K_t: fixed capital stock of time t, 1986 prices

K_{t-1}: fixed capital stock of time t-1, 1986 prices

$I_t - D_t$: the real net fixed capital formation (investment).

4. Factor income shares

Both labour and capital income shares are taken from the *National Income Statistics in Taiwan Area.*

The aggregate output, labour input, capital input and factor income shares may be found in the Appendix.

IV. The Empirical Results

Before using the time series data prepared in the Appendix, I list the different assumptions of the production models:

1. One-factor production function model

The following production functions are estimated:

(a) $GDP_t = \alpha + \beta NE_t$

(a′) $GDP_t = \alpha + \beta NE_t + \delta TIME$

(b) $GDP_t = \alpha + \beta K_t$

(b′) $GDP_t = \alpha + \beta K_t + \delta TIME$

(c) $LN(GDP_t) = \alpha + \beta LN(NE_t)$

(c′) $LN(GDP_t) = \alpha + \beta LN(NE_t) + \delta TIME$

(d) $LN(GDP_t) = \alpha + \beta LN(K_t)$

(d′) $LN(GDP_t) = \alpha + \beta LN(K_t) + \delta TIME.$

The corresponding formulae for average productivity (i.e., Total Factor Productivity) in this case are as follows:

(a) $AP_t = GDP_t/NE_t = \alpha/NE_t + \beta$

(a′) $AP_t = GDP_t/NE_t = \alpha/NE_t + \beta + \delta TIME/NE_t$

(b) $AP_t = GDP_t/K_t = \alpha/K_t + \beta$

(b′) $AP_t = GDP_t/K_t = \alpha/K_t + \beta + \delta TIME/K_t$

(c) $AP_t = GDP_t/NE_t = EXP(\alpha + LN(NE_t)(\beta - 1))$

(c′) $AP_t = GDP_t/NE_t = EXP(\alpha + LN(NE_t)(\beta - 1) + \delta TIME)$

(d) $AP_t = GDP_t/K_t = EXP(\alpha + LN(K_t)(\beta - 1))$

(d′) $AP_t = GDP_t/K_t = EXP(\alpha + LN(K_t)(\beta - 1) + \delta TIME).$

Models (a), (b), (c) and (d) assume no technical progress. Models (a′), (b′), (c′) and (d′) postulate that the rate of technical progress is δ.

The empirical results of the one-factor production function of Taiwan are reported in Table 2.

Table 2 Estimated parameters of the aggregate production function, one-factor model

Model	R^2	Constant	Labour	Capital	Time
(a)	0.94	-17820.	58.2829	–	–
		(-14.5)	(25.3)		
(a')	0.96	-25701.	98.1039	–	-627.90
		(-11.7)	(9.8)		(-4.1)
(b)	0.98	-20524.	–	0.6050	–
		(-31.4)		(51.8)	
(b')	0.99	-18420.	–	0.5001	178.23
		(-32.6)		(26.0)	(6.3)
(c)	0.99	-8.588	2.8417	–	–
		(-51.5)	(71.8)		
(c')	0.99	-1.5379	0.8886	–	0.06
		(-2.6)	(5.3)		(12.0)
(d)	0.86	-9.7702	–	3.1540	–
		(-11.6)		(15.5)	
(d')	0.99	1.5506	–	0.0117	0.08
		(5.3)		(0.1)	(42.8)

2. Two-factor production function model

Production functions with the following forms are estimated:

(a) $GDP_t = \alpha + \beta_1 NE_t + \beta_2 K_t$

(a′) $GDP_t = \alpha + \beta_1 NE_t + \beta_2 K_t + \delta TIME$

(b) $LN(GDP_t) = \alpha + \beta_1 LN(NE_t) + \beta_2 LN(K_t)$

(b′) $LN(GDP_t) = \alpha + \beta_1 LN(NE_t) + \beta_2 LN(K_t) + \delta TIME$

(c) $GDP_t/NE_t = \alpha + \beta(K_t/NE_t)$

(c′) $GDP_t/NE_t = \alpha + \beta(K_t/NE_t) + \delta TIME$

(d) $LN(GDP_t/NE_t) = \alpha + \beta LN(K_t/NE_t)$

(d′) $LN(GDP_t/NE_t) = \alpha + \beta LN(K_t/NE_t) + \delta TIME$.

The formulae for average productivity are:

(a) $AP_t = GDP_t/NE_t$
$= \alpha/NE_t + \beta_1 + \beta_2(K_t/NE_t)$

(a′) $AP_t = GDP_t/NE_t$
$= \alpha/NE_t + \beta_1 + \beta_2(K_t/NE_t) + \delta TIME/NE_t$

(b) $AP_t = GDP_t/NE_t$
$= EXP(\alpha + \beta_1 LN(NE_t) + \beta_2(K_t/NE_t))$

(b′) $AP_t = GDP_t/NE_t$
$= EXP(\alpha + \beta_1 LN(NE_t) + \beta_2(K_t/NE_t) + \delta TIME)$

(c) $AP_t = GDP_t/NE_t$
$= \alpha + \beta_1(NE_t/K_t)$

(c′) $AP_t = GDP_t/NE_t$
$= \alpha + \beta_1(NE_t/K_t) + \delta TIME$

(d) $AP_t = GDP_t/NE_t$
$= EXP(\alpha + \beta_1 LN(K_t/NE_t))$

(d′) $AP_t = GDP_t/NE_t$
$= EXP(\alpha + \beta_1 LN(K_t/NE_t) + \delta TIME)$.

Total factor productivity is defined as:

$$TFP_t = GDP_t / TX_t \quad (4.1)$$

where

TX_t: Total input, total cost.

Because the quantity of labour and capital cannot be added together, the total input must be measured in money value, all the factor prices are values of marginal product computed by using the estimates of the production function, i.e.,

$$TX_t = w_t x NE_t + r_t x K_t \quad (4.2)$$

where

w_t : the factor price of labour
r_t : the factor price of capital.

The growth of total factor productivity is defined as:

$$\begin{aligned} TFP_t^* &= GDP_t^* - (Sl_t^* NE_t^* + Skt^* x K_t^*) \\ GDP_t^* &= 100^*(GDP_t/GDP_{t-1} - 1) \\ NE_t^* &= 100^*(NE_t/NE_{t-1} - 1) \\ K_t^* &= 100^*(K_t/K_{t-1} - 1) \end{aligned} \quad (4.3)$$

where

TFP_t^*: the growth of total factor productivity
GDP_t^*: the growth of real GDP_t
NE_t^*: the growth of labour input
K_t^*: the growth of capital input
Sl_t: the labour income share
Sk_t: the capital income share.

Models (a), (b), (c) and (d) assume no technical progress. Models (a'), (b'), (c') and (d') assume that the rate of technical progress is δ.

Table 3 Estimated parameters of the aggregate production function, two-factor model

Model	R^2	Constant	Labour	Capital	Capital/labour	Time
(a)	0.99	-20370.	16.4033	0.4462	–	–
		(-43.2)	(5.9)	(15.9)		
(a')	0.99	-18885.	4.2873	0.4838	–	135.432
		(-18.0)	(0.5)	(13.4)		(1.5)
(b)	0.99	-8.110	3.1367	-0.3714	–	–
		(-43.3)	(28.6)	(-2.8)		
(b')	1.00	-1.780	1.1562	-0.1934	–	0.0564
		(-3.4)	(6.7)	(-3.2)		(12.5)
(c)	0.91	62.051	–	–	-0.3988	–
		(4.3)			(-3.0)	
(c')	0.98	-32.611	–	–	0.2666	1.1949
		(-12.3)			(12.3)	(48.6)
(d)	0.91	18.878	–	–	3.4493	–
		(5.9)			(5.1)	
(d')	0.99	2.608	–	–	-0.1959	0.0053
		(8.9)			(-3.2)	(86.8)

3. Two-factor translog production function model

The function form is:

$$\begin{aligned} LN(GDP_t) = {} & \alpha + \delta TIME + \beta_l LN(L) + \beta_k LN(K) \\ & + (1/2)\,\delta_{tt} TIME^2 + \beta_{lt} LN(L_t) TIME \\ & + \beta_{kt} LN(K_t) TIME + (1/2)\{\beta_{ll}\,(LN(L_t))^2 \\ & + \beta_{lk} LN(L_t) LN(K_t) + \beta_{kl} LN(L_t) LN(K_t) \\ & + \beta_{kk}(LN(K_t))^2\} + U_t. \end{aligned} \quad (4.4)$$

Factor income share for labour is:

$$S_{lt} = \beta_l + \beta_{lt}TIME + \beta_{ll}LN(L_t) + \beta_{ll}LN(K_t) + U_{lt}; \quad (4.5)$$

and the share for capital is:

$$S_{kt} = \beta_k + \beta_{kt}TIME + \beta_{kl}LN(L_t) + \beta_{kk}LN(K_t) + U_{kt}. \quad (4.6)$$

The following restrictions are imposed on the parameters:

$$\beta_l + \beta_k = 1 \quad (4.7)$$

$$\beta_{lt} + \beta_{kt} = 0 \quad (4.8)$$

$$\beta_{ll} + \beta_{lk} = 0 \quad (4.9)$$

$$\beta_{kk} + \beta_{kl} = 0 \quad (4.10)$$

$$\beta_{lk} = \beta_{kl} \quad (4.11)$$

where U_t, U_{lt} and U_{kt} are disturbances, statistical discrepancies.

By the assumption of the joint normality of the stochastic disturbance terms, we can estimate the two-equation system, consisting of the production function and the factor-share equation. In this chapter, we use the seemingly unrelated regression equation (SURE) method of estimation.

Table 4 Two-factor translog production function

Parameter	Ordinal least square regression		Seemingly unrelated regression	
	Coefficient	t-ratio	Coefficient	t-ratio
α_0	-2.16732	-14.1	-2.14596	-139.5
β_l	1.02046	2.4	0.42882	68.6
β_k	-0.02046	-2.4	0.57118	68.6
δ_t	0.07897	5.4	0.07878	44.4
β_{ll}	6.80912	3.9	0.04708	1.8
β_{kk}	6.80912	3.9	0.04708	1.8
δ_{tt}	-0.00099	-1.7	-0.00095	-11.0
β_{lk}	-6.80919	-3.9	-0.04708	-1.8
β_{lt}	-0.01550	-1.8	0.00578	21.4
β_{kt}	0.01550	1.8	-0.00578	-21.4
DW		-		0.352
System R		0.999		0.995
	Share function			
β_l	0.42811	68.4	0.42882	68.6
β_{lt}	0.00580	21.4	0.00578	21.4
β_{ll}	0.04219	1.6	0.04708	1.8
β_{lk}	-0.04219	-1.6	-0.04708	-1.8
DW		-		1.003

Test of Hypotheses

In the simultaneous equation models of Taiwan, each time the series variable has 39 observations, five constrained parameters in the production function, and two constrained parameters in the factor share function. The degree of freedom is equal to 34 (df=39-5) in the factor share function. The probability of rejecting the null hypotheses (zero value) is as following:

Table 5 The t distribution

Degrees of freedom		Probability of rejecting null hypotheses					
		0.25	0.10	0.05	0.025	0.010	0.005
30	t-ratio {	0.683	1.310	1.697	2.042	2.457	2.750
40		0.681	1.303	1.684	2.021	2.423	2.704

Note: Two-tailed test.

From the critical values, we find that, under the probability of 2.50 per cent, only the parameters of β_{11}, β_{KK} and β_{1k} cannot be rejected (accept the null hypotheses). And all the other parameters are rejected (reject the null hypotheses, accept the non-zero hypotheses).

Technical progress

The technical progress grew very rapidly in Taiwan before 1980, but it began to slow down afterwards. The computed growth rate in 1952-1960 was 7.30 per cent, which was very high; in 1981 to 1989, the growth rate in Taiwan decreased to 4.65 per cent.

Table 6 Technical progress and total factor productivity of Taiwan computed from translog production function

Period	Technical progress	Total factor productivity progress
1952-60	7.30	7.65
1961-70	6.50	6.87
1971-80	5.63	6.05
1981-89	4.65	4.99
1952-89	6.02	6.36

Total factor productivity progress was also higher in Taiwan before 1980, but these growth rates slowed down steadily after 1952. For the period 1952-1960, average total factor productivity grew at a rate of 7.65 per cent; between 1981 and 1989, the growth rate was only 4.99 per cent.

Average labour and capital productivity progress

In the period of 1952 to 1989, the average labour productivity growth rate in Taiwan was 5.91 per cent. Comparing growth rates in different periods, we find that the growth rate was slowing down over time.

Table 7 Average labour and capital productivity progress of Taiwan, from translog production function

Period	Labour	Capital
1952-60	6.49	8.48
1961-70	5.84	7.74
1971-80	5.80	5.88
1981-89	5.68	3.42
1952-89	5.91	6.35

During the 1952-1989 period, the average growth rate of the labour and capital productivity in Taiwan were 5.91 per cent and 6.35 per cent respectively. These growth rates both showed a decreasing trend in the four successive periods.

Sources of computed real GDP growth in Taiwan (Table 8)

First, from the translog production function we compute the contribution from labour, capital, total factor productivity and technical progress to the growth of GDP in Taiwan. During the period 1952 to 1989, the average growth rate of real GDP, labour, capital, total factor productivity, technical progress and unexplained residual are 8.95, 1.57, 1.01, 6.36, 5.98 and 0.34 per cent respectively. We find that the total factor productivity progress was explained entirely by technological progress.

Next, the relative contributions of labour employment, capital, total factor productivity, technical progress and the residual are 16.94 per cent, 11.27 per cent, 71.06 per cent, 67.26 percent and 3.80 per cent respectively. The most important source of growth is attributable to either total factor productivity or technical progress.

Finally, in these four periods, we find that the importance of total factor productivity is decreasing, while the relative importance of capital is increasing.

Table 8 Relative contributions of the sources of growth computed from translog production function

Period	Growth rate of					
	GDP	Employment	Capital	TFP	Technical	Residual
1952-60	8.78	0.97	0.14	7.65	7.30	0.35
1961-70	8.80	1.46	0.47	6.87	6.50	0.37
1971-80	9.65	2.10	1.50	6.05	5.63	0.42
1981-89	8.45	1.64	1.83	4.98	4.65	0.33
1952-89	8.95	1.57	1.01	6.36	6.02	0.34
Period	Relative contribution of					
	GDP	Employment	Capital	TFP	Technical	Residual
1952-60	100	11.03	1.71	87.12	83.14	3.98
1961-70	100	15.95	5.16	78.06	73.86	4.20
1971-80	100	20.89	15.86	62.69	58.34	4.35
1981-89	100	18.91	21.47	58.93	55.03	3.90
1952-89	100	16.94	11.27	71.06	67.26	3.80

V. Concluding Remarks

In this chapter, two models of production are analysed. In the one-factor model, aggregate productivity is determined by only one-factor input. The production functions are divided into a linear function and a log-linear function. From the estimated results, we find that both models have high values for R^2 (coefficient of determination); the parameters are significant in terms of the t-ratio test.

When technical progress is introduced, all the one-factor models improve in terms of R^2. With the exception of the log-linear form, the coefficients of labour, capital and technical are very significant.

In the case of the two-factor model, R^2 improves. The exception is the log-linear form. In some cases, the coefficients of capital or labour are negative. The fact that the technical progress in each two-factor model shows a positive sign and is statistically significant proves that the source of aggregate productivity growth is attributable to the technical progress.

The two-factor translog production function model of Taiwan involves very complicated estimation. We make use of ordinary least square regression as well as seemingly unrelated regression applied to the simultaneous equation system of translog production function and the factor share function. We find that the result derived from the seemingly unrelated method is more reasonable than the ordinary least square method.

The growth rates of computed aggregate productivity, per-capita labour and capital productivity, total factor productivity and technical progress are higher initially but slow down over time. These results suggest that it will be more difficult to continue its past good performance as Taiwan's economy become more developed.

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Appendix

Table A.1 The aggregate real output (GDP), employment (NE), fixed capital stock (K), income share of capital (Sk) and labour (Sl), Taiwan area, Republic of China

Year	GDP	NE	K	TIME	Sl	Sk
1952	1620.9	292.9	39179.0	1	42.94	57.06
1953	1772.2	296.4	39253.3	2	40.78	59.22
1954	1941.2	302.6	39355.7	3	46.54	53.46
1955	2098.6	310.8	39470.2	4	46.26	53.74
1956	2214.1	314.9	39556.9	5	47.47	52.53
1957	2377.1	322.9	39662.7	6	46.63	53.37
1958	2536.6	334.0	39758.2	7	47.18	52.82
1959	2730.6	342.2	39884.8	8	46.10	53.90
1960	2902.9	347.3	40046.7	9	46.57	53.43
1961	3102.6	350.5	40239.8	10	45.42	54.58
1962	3347.8	354.1	40447.2	11	48.52	51.48
1963	3660.9	359.2	40654.2	12	47.83	52.17
1964	4107.6	365.8	40904.1	13	48.14	51.86
1965	4564.9	376.3	41156.2	14	49.16	50.84
1966	4971.8	385.6	41504.8	15	50.54	49.47
1967	5504.3	405.0	41974.4	16	51.32	48.68
1968	6009.1	422.5	42573.8	17	52.95	47.05
1969	6546.8	439.0	43316.2	18	53.74	46.26
1970	7291.3	457.6	44133.2	19	53.97	46.03
1971	8231.5	473.8	45047.2	20	55.94	44.06
1972	9327.7	494.8	46191.3	21	55.00	45.00
1973	10524.7	532.7	47517.6	22	53.49	46.51
1974	10647.0	548.6	49026.8	23	56.39	43.61
1975	11171.7	552.1	50861.3	24	59.00	40.99
1976	12720.2	566.9	53110.1	25	58.32	41.68
1977	14016.3	598.0	55273.5	26	58.91	41.09

Table A.1 (Continued)

1978	15921.7	622.8	57427.3	27	59.53	40.47
1979	17223.1	642.4	59841.9	28	60.69	39.31
1980	18480.6	654.7	62715.6	29	60.90	39.10
1981	19619.5	667.2	66213.8	30	62.59	37.41
1982	20316.2	681.1	69658.7	31	63.60	36.40
1983	22032.3	706.7	72915.1	32	62.73	37.27
1984	23430.8	730.8	75857.9	33	63.03	36.97
1985	24737.9	742.8	78761.2	34	63.37	36.63
1986	28551.8	773.1	81115.5	35	61.06	38.94
1987	32229.9	802.0	87836.4	36	60.54	39.46
1988	34969.5	810.5	91195.6	37	62.29	37.71
1989	38785.5	826.2	96179.7	38	63.74	36.26
1990	42220.0	828.3	101553.0	39	65.76	34.24

Notes: GDP and K (at 1986 constant prices, 100 million NT$);
NE (10 thousand persons/year);
Sk and Sl are percentages.