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Can China's Growth be Sustained? A Productivity Perspective

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Summary. — China's gradual approach to economic transition has resulted in sustained high growth. However, in recent years Chinese economists have increasingly referred to the growth pattern as "extensive," generated mainly through the expansion of inputs. Our investigation of the Chinese economy during the reform period finds that reform measures often resulted in one-time level effects on total factor productivity (TFP). China now needs to adjust its reform program toward sustained increases in productivity. Market and ownership reforms, and open door policies have improved the conditions under which Chinese firms operate, but further institutional reforms are required to consolidate China's move to a full-fledged market economy.

Key words — growth accounting, total factor productivity, economic reform, China, Asia

1. INTRODUCTION

The past three decades have witnessed miraculous achievement in the economic development of China. Since the economic reform process started in 1978, Chinese *per capita* income has increased eightfold. But the piecemeal and gradual reform strategy pursued by China means that the market still has not permeated the entire economy. Property rights and related institutions are far from the ideal textbook model. However, as in the East Asian NICs, key ingredients of China's reform strategy have been education, high savings, and export orientation. A controversial aspect of the present strategy is also the attempt to preserve an undervalued currency to promote export.

While China's specific approach to economic transition has been successful in promoting rapid economic growth, in recent years economists have been increasingly concerned about the pattern of "extensive" growth (Wu, 2006), a term often used to describe Soviet growth during the Cold War period. Its main characteristic is growth generated mostly through the expansion of inputs and only marginally through increased productivity (Ofer, 1987). From the late 1970s to the early 1990s, China's growth depended more on productivity growth and less on increased capital than other East Asian NICs at a comparable stage of their development. However, since then growth in capital inputs has exceeded GDP growth, often substantially. Some recent studies have reported a prolonged slowdown in total factor productivity growth (Zheng & Hu, 2006).

This situation might have been due to the fact that China's productivity growth before the mid-1990s was driven mainly through one-time dramatic improvements in policies. But changes in policies may temporarily affect a country's growth rate by affecting the level of total factor productivity (TFP) without affecting its growth rate in the long run. Klenow (2001) notes "China is a fast grower not because its institutions are among the best but because it has improved its institutions so much in the last two decades." Several studies have predicted that if China does not keep its reform momentum, its productivity as well as *per capita* income growth might slow down.

There are two major aspects of China's recent economic development that have been particularly worrisome. At the macro level the growth has been mainly investment-driven, creating a series of imbalances in the economy. Stabilization measures have been taken to prevent rapid economic growth from becoming overheated. At the micro level, the financial performance of many firms is poor, with low efficiency and lack of technological innovations. There is an expanding literature trying to explain this pattern of development, discussing whether extensive growth is sustainable and what China's future development strategy should be. In this paper, we approach the issue of sustainability regarding China's growth

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through a productivity perspective, which is something touched upon in several studies but yet to be fully explored.[1]

Although savings and investment are considered to be central in the theory of economic development (Lewis, 1954), a growing body of research suggests that, even after physical and human capital accumulation are accounted for, TFP seems to explain the bulk of cross-country differences in the level and growth rate of GDP *per capita* (Easterly & Levine, 2001). Several studies have pointed out that differences in physical and intangible capital cannot account for the large income differences across countries today. Savings-rate differences are of limited importance. What is most important is TFP, and a theory of TFP growth is needed to understand the large international income differences (Prescott, 1998). More effort toward modeling and quantifying TFP is required (Easterly & Levine, 2001), and many argue that TFP should be the focus of growth research (e.g., Klenow, 2001).[2]

In the next section, we characterize China's growth pattern by decomposing growth into factor accumulation and TFP growth, and we review the literature on Chinese TFP growth. In Section 3, we examine the process in which capital is accumulated, and analyze the determinants of China's high rate of accumulation. In Section 4, we assess whether capital is allocated and utilized efficiently. In Section 5, we summarize what we have learned about the Chinese growth pattern from a productivity perspective and comment on policy challenges in improving the allocation of factors and the efficiency of their utilization. Section 6 concludes.

2. CHINA'S GROWTH PATTERN SINCE 1978

China has experienced three major waves of reform since 1978. The first was the reform of collective farming with the household-responsibility system and the upward price adjustment for some agricultural products, which resulted in a rapid increase in agricultural productivity and output for several years (Wen, 1993).[3] The second wave started in the middle of the 1980s and continued into the early 1990s, during which managers and workers in state-owned enterprises were gradually provided with greater incentives to improve efficiency. Township-village enterprises flourished, helping shift much of the rural labor force to industries (Goodhart & Xu, 1996). The third wave started with Deng Xiaoping's tour of Southern China in 1992. Many state and collective firms were privatized, foreign direct investment poured in, and exports accelerated.

A noteworthy feature of China's growth during 1978–95 was its reliance on productivity growth. Relative to other rapidly growing Asian economies at a comparable stage of development, China's growth during this period was less dependent on growth of capital and labor (World Bank, 1997). In most East Asian countries, growth of capital exceeded GDP growth, often substantially, but not in China where GDP grew faster than capital, suggesting that factors other than capital accumulation were important determinants of GDP growth during the early reform years.

Empirical studies estimate that TFP growth accounted for 30–58% of China's growth during 1978–95 (Maddison, 1998; World Bank, 1997). Hu and Khan (1997) found that an average TFP growth of 3.9% explained more than 40% of China's growth during the early reform period. However, Krugman (1994) pointed out that it is difficult to account for China's growth because the quality of the numbers is poor. Young (2003) also questioned the notion that Chinese growth during the economic reform period was very different from that of other countries, by focusing on the nonagricultural productivity. After adjusting official data, he found growth comparable to that previously experienced by other rapidly growing economies. After accounting for growth of labor (largely due to increased labor force participation), the shift of labor out of agriculture, and rising educational levels, he found nonagricultural labor productivity growth at 2.6% and TFP growth at 1.4% per year.

Although estimates of China's productivity growth during the reform period differ, several factors behind it can be identified. First, the success of the rural reform from the late 1970s to the early 1980s resulted in a temporary surge in TFP in agriculture. Second, industrial reforms provided individual firms, managers, and workers with greater incentives to improve efficiency, and especially township-village enterprises (TVEs) achieved higher efficiency levels and TFP growth than state firms (e.g., Goodhart & Xu, 1996; Woo *et al.*, 1994; Zheng, Liu, & Bigsten, 1998). Third, rising labor force participation rates, improvements in educational attainment, the transfer of labor out of agriculture, and the narrowing the technology gaps between China and developed economies also contributed to the TFP growth. However, some of these factors only had a one-time level effect on TFP. Agriculture productivity growth slowed significantly from around 1983 and industrial productivity even recorded a decline during 1993–96. So future TFP growth may not match the levels witnessed in the past (Heytens & Zebregs, 2003; Liu, 2000; Maddison, 1998), unless further reforms are undertaken.

As some economists predicted, while TFP growth was satisfactory up to the early 1990s, reports of productivity slowdown started to emerge around the year 2000. Jefferson, Rawski, Wang, and Zheng (2000) investigated industrial productivity during 1980–96 finding long-term productivity growth but at declining rates during the 1990s. Zhang (2002) also found a downward trend for the aggregate economy during 1993–98, noting that it had become increasingly difficult to maintain GDP growth for a given increase in investment. Zheng and Hu (2006) found that TFP growth fell dramatically

Table 1. *China: growth accounting with human capital 1978–95 and 1995–2005*

	1978–95 (pct per year)		1995–2005 (pct per year)	
Average growth				
GDP	10.11		9.25	
Factors				
Capital	9.19		12.38	
Quality adjusted labor	3.60		2.59	
$TFP^{0.6}$	3.16		0.79	
$TFP^{0.5}$	3.72		1.77	
$TFP^{0.4}$	4.27		2.74	
		Share of total		Share of total
Contribution to GDP growth				
Total GDP	10.11		9.25	
Factors	6.40	0.63	7.49	0.81
Capital	4.60	0.45	6.19	0.67
Quality adjusted labor	1.80	0.18	1.30	0.14
$TFP^{0.5}$	3.72	0.37	1.77	0.19

Note: $TFP^{0.4}$ refers to the estimates using 0.4 as capital share, and so on so forth.

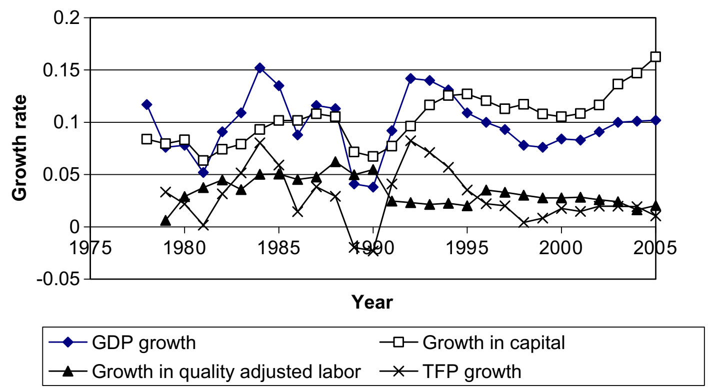

Figure 1. *Growth in input, output, and TFP (1978–2005, capital elasticity = 0.5).*

during 1995–2001, accounting for as low as only 7.8% of GDP growth. Whereas TFP had risen by 3.2–4.5% per year before 1995, it rose by only 0.6–2.8% per year after that. The OECD (2005) estimated that annual TFP growth averaged 3.7% during 1978–2003, but slowing to 2.8% by the end of that period (Economist, 2005). This was due to a decline in the growth rate of total factor productivity from 1993.

The overall decline in TFP growth is clearly seen if one divides the period 1978–2005 into two sub periods 1978–95 and 1995–2005. Average growth of capital exceeded growth of GDP by 3.13% in the second period (Table 1 and Figure 1).[4] The relative contribution of TFP growth to GDP growth also declined, so that growth was largely driven by growth of capital, growing at the amazing rate of 12.38% per year. This increased the capital/labor ratio very fast (Table 2 and Figure 2), which in turn led to an increase in labor productivity. The increase was relatively modest because the effect of capital deepening was counterbalanced by the slowdown of TFP growth. Figure 3 shows the time series of H–P filtered TFP measure for the entire data period. TFP averaged 3.3% during 1978–95, and it slowed down to 1.9% during 1995–2005.[5]

Explanations for changes in TFP growth are often controversial, but the slowdown during 1995–2005 coincides with sluggish rural income growth and widespread industrial inefficiency. "Human capital, land, and other resources were misallocated, underemployed, and inefficiently used" (OECD, 2002). The growth has increasingly relied on capital accumulation, while growth of labor has declined from 2.34% for 1978–95 to 1.07% for 1995–2005.

In spite of all these problems the economy has not shown any signs of slowing down. Instead the government has had to use a combination of economic and administrative measures in 2004–2007 to cool off the investment boom. To understand how extensive growth emerged in China and whether growth can be sustained, we need to analyze factor accumulation, factor allocation, and TFP growth. We start by discussing capital accumulation.

Table 2. *Growth in factor productivity and capital labor ratios*

	1978–95	1995–2005
GDP growth	10.11	9.25
Growth in capital stock	9.19	12.38
Growth in capital productivity	0.84	−2.78
Growth in quality adjusted labor	3.60	2.59
Growth in quality adjusted labor productivity	6.14	6.45
Growth in capital–labor ratio	5.39	9.52

Source: NBS, and author estimates.

3. CAPITAL ACCUMULATION

Relative to Western economies, China still has a low capital/labor ratio. Labor is abundant, but human capital measured as the average level of education is still low. Thus, investment in both physical and human capital is important for growth. But in this section we discuss the results of excessive capital accumulation since 1990 and the policy supporting it. In the next section, we will discuss how capital has been allocated and utilized and its impact on TFP.

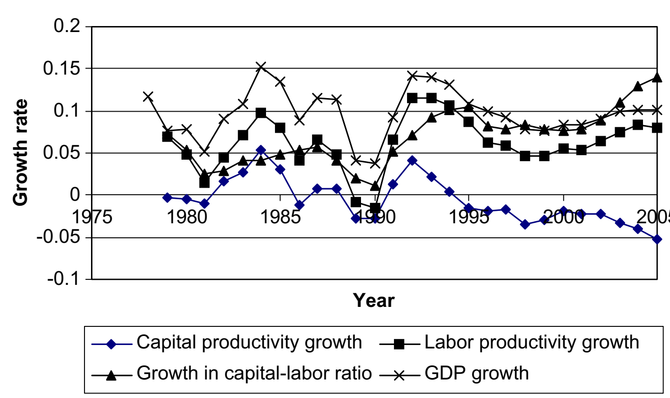

Figure 2. *GDP growth, growth in ratios (1978–2005). Labor was adjusted for quality change.*

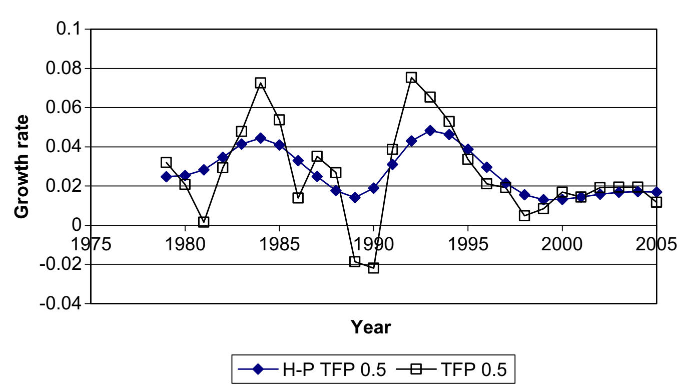

Figure 3. *H–P estimates compared with Solow residuals (capital elasticity = 0.5). Labor measure adjusted for change in labor quality. H–P estimates correspond to a smoothing parameter of 6.25 recommended in Ravn and Uhlig (2002).*

After a recession in 1989–90, China's leadership indicated its determination to market reforms, and investment rapidly increased reaching 43.5% of GDP in 1993 (Shane & Gale, 2004). The investment boom generated real estate bubbles in early 1990s and triggered a two-digit inflation, peaking at 27% in 1994. The burst of the housing bubble and retrenchment policies slowed investment. Starting from mid-1990s, consumption and exports became more important, while China found it difficult to sustain an 8% GDP growth during the Asian financial crisis. Investment picked up speed in 2000 when the government increased spending on large-scale infrastructure projects, and at the same time both foreign and domestic investments were booming in manufacturing. The winning of the contract to host the 2008 Olympic Games further encouraged government spending on construction projects; and China's WTO membership in 2002 also stimulated foreign and domestic investment in China. As investment in factories and other construction as well as roads and other infrastructure reached unprecedented levels, gross capital formation rose from 36% in 2000 to 43% in 2003—about 5 percentage points above China's 1978–2003 average (Shane & Gale, 2004). All this investment meant that GDP grew on average by over 9% per year from 1995 to 2005.

Two aspects of central government policy since the mid-to-late 1990s supported this extraordinary investment growth. First, key input prices such as land, electricity, and other utilities, including water were kept low through subsidies and controlled pricing. In many cases land was allocated for development at zero-cost, and electricity for foreign direct investment was sold at half price. Second, cheap finance was channeled into industry, particularly to SOEs and other large companies, often effectively at zero-cost. This was made possible by the high savings rate, which averaged 40% of GDP for most of the 1990s and has recently grown to close to 50% (IMF, 2005). The investment boom was also fueled by local governments, over which the central government had limited control following fiscal decentralization in 1994 (Lin & Liu, 2000; OECD, 2002, p. 57). They constructed plants and infrastructure even if it made little economic sense.

Besides high growth, China's investment strategy has had three side-effects. First, the buildup of excess capacity led to deflation in output prices (Lin, 2004). At the macroeconomic level, investment in inventories has been negative since the second half of 1999, signaling excessive production capacity (Zhang, 2006). By 2004, 90% of manufactured goods were in oversupply. In the automobile and steel sectors there was evidence that excess capacity was beginning to drive prices down (China Business Review, 2005). This could reduce profits and result in a new accumulation of non-performing loans in the banking system, reversing some of the progress that has been achieved there in recent years (Prasad, 2005). [6]

A second effect of high (and excessive) investment in industries is the official turn toward export markets, which partly explains the growing effort of Chinese businesses in recent years to go global. Globalization is increasingly viewed as an alternative to "domestic structural complexity" (Project Syndicate, 2005). But China's exports in part rely on what may be an unsustainably low fixed exchange rate. China gradually depreciated the currency from 3 yuan per dollar in 1985 to 5.76 in 1993, then it was depreciated to 8.62 in 1994. During 1997–2005 China maintained its exchange rate at approximately 8.28, a rate that some economists suggest is much too high. Under pressure from abroad, particularly the United States, the currency has appreciated to currently about 7.00 yuan per dollar.

A further side-effect of high investment is a huge trade surplus, especially with the United States. China's stock of foreign reserves has risen sharply since 2001, and in March 2007 it surpassed one trillion US$ and continues to increase fast. China is thus facing an excessive growth of credit and money supply, which is fueling another real estate bubble in the major cities.

A vicious circle seems to have developed. The high investment rate has built up excess capacity, which has caused deflationary pressure on manufactured goods, cutting profit margins, and accumulating non-performing loans in the banking system. At the same time, using exports to absorb excess capacity has resulted in a large buildup of foreign reserves and rapid increase in the money supply, which in turn is fueling another round of excessive lending and investment, generating more excess capacity.

While the production system has so far been generating excess capacity on its own, radical reforms in education, health, and pensions systems have been contributing to the problems. A high domestic savings rate has made it possible for China to invest on a very large-scale. An important reason for the high savings is that "the transition from planned to market economy has involved a massive shift of financial risk from state-owned enterprises to households, thereby creating a large perceived need for precautionary savings by households to fund anticipated educational, medical, and retirement expenses" (Kroeber, 2005). But household savings, while high, do not alone explain the countries' high savings-rate. "As corporations have improved their performance, their savings have risen and now account for almost half of national savings. Corporations have an incentive to retain their earnings in order to self-finance their investments" (Dunaway & Prasad, 2006). High government savings of closing to 6% of GDP also contribute (Kuijs, 2006).

The government has not been willing or able to enforce strict environmental regulations, so excessive investment in manufacturing has also led to misuse of the country's natural resources, including energy, and to degradation of the environment. About 70% of the country's rivers and lakes are seriously polluted, and WHO reports that two-thirds of Chinese cities have air quality below standard, of which nine are in the world's top ten of the most polluted, especially with high carbon monoxide. The government estimates that about 400,000 people die each year of diseases related to air pollution (Hunt, 2006).

The export strategy requires easy access to ports and, given China's labor abundance, concentration on low value-added, low technology, non-branded goods. The benefits of growth have not been shared evenly across regions, skill levels, or industrial sectors, creating increasing gaps between rich and poor. The newly rich have achieved an economic standard vastly different from that of the poor (Gilboy & Heginbotham, 2004). Chinese policy-makers are at present pushing the notion of "harmonious development", which suggests that measures to spread the benefits of growth more equitably are under consideration.

4. ALLOCATION AND UTILIZATION OF CAPITAL

As much as two-thirds of China's investment has been in infrastructure such as roads, dams, and public buildings. Much of the remainder has gone to machinery and equipment in manufacturing (Shane & Gale, 2004). Investments in agriculture are only about 2%, in spite of the fact that the sector accounts for 15% of GDP.

The state sector, although contributing only one-third of China's GDP, still controls much of the country's capital (Wu, 2000). For example, most "private" investments are made by state-owned or collectively owned enterprises, funded by internally generated funds or loans from state-owned banks. During 1993–2000 more than 60% of all loans went to state-owned enterprises (Wolf, 2005). Foreign investment has increased, but still accounts for only about 5% of total investment (Shane & Gale, 2004).

There are signs of too much investment in manufacturing for export (Blanchard & Giavazzi, 2006), so that investments on the margin have low returns. In the 1980s and 1990s it took $2–3 of new investment to produce $1 of additional growth, now it needs more than $4 (Zhang, 2006). None of the high performing East Asia NICs such as South Korea, Taiwan, and Japan, had such high incremental capital/output ratios at comparable stages in their development. India, often compared unfavorably with China, is more efficient in this regard (Economist, March 2004).

State-owned enterprises are clearly another major source of inefficiency (OECD, 2005). Their poor performance has been caused, at least to some extent, by the government to achieve certain social policy goals, but it has also been due to their lack of flexibility caused by extensive government interventions in their economic management (OECD, 2002). The inefficiencies have lead to low-profits and escalating debts, and this has led to further government interventions to prop the poor firms up by transferring resources from the better performing firms to the bad firms. The SOEs also receive preferential treatment in various forms by the government and are often protected from competition. There is a large spread in returns between the performance of the small number of state firms that do well and the bulk of them that do very poorly. OECD (2005) estimated that the median SOE earned a rate of return of only 1.5% in 2003.

Another source of misallocation has been government interventions in economic activities and coincident corruption. The growth-promoting policy initiated by the central government has been interpreted at the local level as growth at any cost. Achievement projects and image projects have run rampant as local governments competed for a nominal share of increased GDP (China Daily, 2005). There has then emerged what Hunt (2006) calls China's trilogy of local company, local government, and local bank. Each has a vested interest in building whatever plant is in vogue, whether a steel mill, power station, air-conditioner factory, copper-tube plant, whatever. Very often these plants have been financed by zero-cost capital, with corrupted officials benefiting financially in the process.

A source of both misallocation and underutilization is the fragmentation of Chinese markets because of local protectionism. OECD (2002) noted that in contrast to the formerly centrally planned economies of Eastern Europe, China's production facilities were sub-optimal in both scale and scope, resulting in wasteful duplication. It reported that there were 200 producers of automobiles, most of which made only a few thousand units per year, and there were nearly 8,000 cement firms compared to 110 in the United States, 51 in Russia, 58 in Brazil, and 106 in India.

According to Gilboy (2004), the political risks of challenging competitors and their local patrons are responsible for this fragmentation. Few Chinese firms develop alliances with or invest in companies in other provinces. Gilboy cites one recent survey of 800 companies that have conducted domestic mergers and acquisitions as finding that 86% invested in firms within their own city, 91% within their own province. Young (2000) found a negative relationship between industry-level specialization and growth along with converging production structures in Chinese provinces. The finding appears to be in conflict with the increased international openness since the late 1970s and is not consistent with the objectives of economic reforms (Batisse & Poncet, 2004). One explanation is that inefficient firms often seek local government protections, resulting in close local political-business relations that can separate a region from the rest of the economy (OECD, 2002).

Although by some measures the past two decades have seen a gradual decline in regional protectionism (Gong, Xu, & Tan 2003), a recent study cited in Gilboy (2004) revealed that Beijing and Shanghai had been identified as leading centers of local protectionism; among the industries most affected by such protectionism were pharmaceuticals, electrical machinery, electronics goods, and transport equipment; and private firms suffered the most, foreign-funded firms the least, which suggests that the burden of domestic protectionism falls most heavily on Chinese firms.

The scale of FDI has been large, starting from almost zero in 1990 to 6% of GDP in the early 1990s and falling back to about 3.5% since 2000 with an absolute volume of 60 billion US$ in 2004 (China Business Review, 2005). According to OECD (2005), slightly more than one-quarter of this inflow is actually retained earnings; almost half comes from Hong Kong, China, or tax havens, and about one-third from other Asian countries. In addition, a significant part presumably originates in unidentified countries and may include Chinese capital that has been pretended as FDI in order to take the tax advantages enjoyed by foreign firms.

Huang (2005) shows that the favoritism shown toward FDI relative to domestic investors is very modest compared to that shown toward the SOEs. So the key policy problem concerns the reluctance of the government to support the growth of the domestic private sector. It seems as if the government finds FDI to be less of a challenge to the political system than an emerging indigenous entrepreneurial class.

Most FDI in China comes from small and medium-sized foreign companies, who bring relatively little new and advanced technology or organizational know-how. According to econometric estimates it even seems to be the case that the productivity of FDI is slightly lower than that of private domestic companies (OECD, 2005). So the role of foreign-controlled companies in raising productivity should not be overstated.

A major current government policy concern is that China has not invested in long-term technological research like Japan, South Korea, and Taiwan did during 1970s–80s. A historically significant characteristic of China's economic development is that China became one of the major economies in the world "without having a group of internationally competitive large firms" (Nolan, 2005). The main mode of import of technology for Chinese firms is through the purchase of foreign manufacturing equipment. Chinese state firms often insist on importing technology, which cannot be absorbed at their stage of development. It often comes in complete packages such as assembly lines. According to Gilboy (2004), this type of investments made up more than 80% of China's technology imports following the two decades since economic reform, while licensing only accounted for 9%, "know-how" services 5%, and consulting 3%. He further pointed out that even in the recent decade large- and medium-sized Chinese industrial firms spent less than 10% of the cost of imported equipment on efforts at indigenizing technology (e.g., telecom equipment 8%, electronics 6%, and industrial machinery 2%).[7] Having realized the seriousness of the problem, the Chinese government announced an R&D

spending plan of 136 US$ in 2006 that exceeded Japan's spending the same year. However, critics say that Chinese patents registered in industrialized countries are still low and rising cases of academic fraud also cast considerable doubt on the efficiency of the Chinese R&D management.

5. POLICY LESSONS FROM A PRODUCTIVITY PERSPECTIVE

After reviewing China's recent growth performance, there are a few lessons that might be learned from a productivity perspective. Although the growth accounting framework has long been used as an instrument for economic planning in China, the contents of TFP are not well understood. Some economists used to believe that the framework was not suited for the Chinese situation (e.g., Yi, Fan, & Li, 2003), while economic forecasts frequently relied on it. In many cases, applications to China have been rather mechanical. During the early reform period, sometimes TFP estimated with Solow residual was taken for granted as an exact measure of technological progress. Later on when people started to realize that TFP might be influenced by many factors, some critics regarded it as practically useless or irrelevant. In fact, if properly implemented and interpreted, growth accounting is a valuable tool (Bosworth & Collins, 2003), which can improve our understanding of China's growth experience. In the extreme case of extensive pattern of growth like China seems to be experiencing now, growth accounting methods are sensitive enough to pick up significant changes in productivity performance if parameters of production are carefully chosen.

Extensive growth refers to a growth strategy based on the expansion of inputs (Irmen, 2005). A key feature of the extensive growth model is that capital grows faster than GDP (Ofer, 1987). This phenomenon is related to the concept of level effect, which is not sustainable in the long run. On the other hand, sustained growth in a country's *per capita* income can only occur if there is a rise in total factor productivity (Krugman, 1994). Sustained productivity growth is referred to as growth effect in the terminology of growth modeling. Failure to distinguish the difference between level effect and growth effect in practice may lead to erroneous analyzes.

In the late 1990s, Chinese planners were preoccupied with maintaining growth of 8% in the face of the East Asia financial crisis. Some forecasts relied on China's ability to maintain high capital formation, but if growth of capital exceeds GDP growth, one ends up with "extensive growth." For example, using a standard growth accounting procedure with a capital elasticity of 0.6 and TFP growing at 3% per year, Chow and Li (2002) predict that China would be able to sustain a growth of 7% if capital formation of 30% of GDP is maintained. However, a 30% capital formation rate in their context could result in about 8% growth rate in capital stock.

If one instead assumes a smaller output elasticity of capital, say 0.5, and capital stock increases 8% per year while the labor force grows slightly above 1% as it has in the last decade, one needs a TFP growth of 3.5% to achieve 8% GDP growth. It will require the contribution of TFP to GDP growth to reach 44%, which may not be an easy thing to achieve in reality. If we take this case as a benchmark, Chinese planners have been overly optimistic, with forecasts of TFP's contribution to output growth (made in the year 2000) estimated at 54% to 60% for the 10th and 11th five-year plans (Song & Li, 1999–2000). Researchers at the State Planning Committee also assumed TFP growth increasing from 3% to 4.5–5% in forecasting economic growth from 2001 to 2015 (Research Group, 2000). Although forecasts of TFP's contribution to output growth after the 10th five-year plan ended were adjusted downward to less than 30%, researchers at the Development Research Center of the State Council predicted that TFP growth brought about by urbanization, investment in human capital, economic, reform and technological innovation would make an increasing contribution to economic growth (People's Daily, 2005).[8]

A more recent study by Liang and Yi (2005) went even further. Assuming capital elasticity of 0.4 and 0.3, they found that 36.2% and 44.3% of GDP came from TFP for the period 1978–2004. Both figures exceeded the contributions from capital, and specifically the higher estimate of 44.3% contribution from TFP is corresponding to a much smaller figure of 27.7% from capital, which is not consistent with most growth accounting studies in the literature. The studies based on such estimates of TFP did not seem to have noticed that China's growth has been investment-driven during the last decade. Empirical work on productivity performance should pay more attention to those careful analyzes of the real situation in China (e.g., Wu, 2006). Kuijs and Wang (2006) point out that continued investment and industry-led growth are almost certainly unsustainable if China's current growth strategies are unchanged. It would require the investment-to-GDP ratio reaching unprecedented high levels of 55% on average in 2014–24 in order to maintain GDP growth of 8% per year.

It is not clear whether investment has been used by the government as a last resort to counterbalance business cycles when TFP growth did not deliver as expected. During 1978–95 period, the TFP share of GDP growth was basically procyclical, while during 1995–2005 the reverse seems to have occurred by the end of the period (Figure 4). Growth was clearly driven by an increasing share of capital stock, while the TFP share decreased. Had there been a deeper understanding of the forces behind TFP growth, economic reform policies could have been better designed in several respects. Some of these are related to rather standard results in the growth and productivity literature.

(a) *Structural economic reforms*

China has since 1978 pursued a gradual and piecemeal reform strategy which has been very successful, but Prasad and Rajan (2006) argue that China, with its rising market orientation and increasing integration with the world economy, may find that its strategy does not work as well as before. They argue that it would probably make sense to take the opportunity with the favorable domestic and external circumstances to initiate bolder reforms and to tackle structural problems.

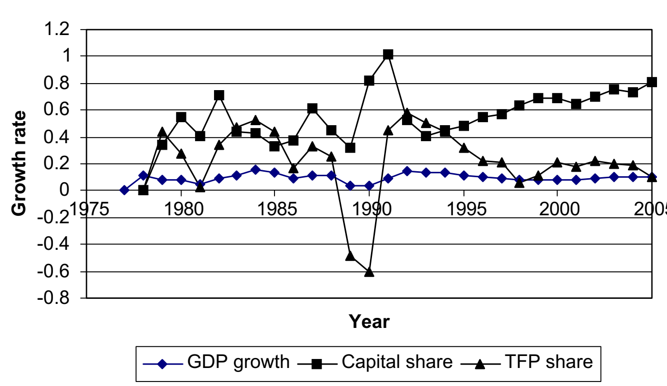

Figure 4. *Counterbalancing business cycles in China (capital elasticity = 0.5). Labor measure was adjusted for quality change.*

(i) *A half-reformed system is not efficient*

The piecemeal and gradual reform strategy pursued by China means that the market still has not permeated the entire economy. "Incremental reform releases parts of the economy from central control, while maintaining, for a sustained period, many of the distortions of the central plan, and the freed parts of the economy find it profitable to take the rent-seeking opportunities implicit in the remaining distortions of the economy" (Young, 2000). The current growth pattern was made possible partly because of controlled pricing in land deals, utilities (water and electricity), energy, and capital. In a way, all these can be seen as subsidies to China's export oriented strategy. According to one estimate, subsidies to petrol-related production inputs might have accounted for 1% of GDP (Ha, 2005).

Change in TFP can be decomposed into technical progress and efficiency-change. "The former is associated with changes in the best-practice production frontier, and the latter with other productivity changes, such as learning by doing, improved managerial practices, and changes in the efficiency with which a known technology is applied. Identifying TFP growth with technical progress ignores the importance of technical efficiency-change, especially in less-developed countries" (Felipe, 1999). It has long been recognized in the applied productivity analysis literature that introducing new technologies in a country without realizing the potential of old equipments might be meaningless (Nishimizu & Page, 1982; Schmidt, 1985). For example, rent-seeking opportunities may lead to state firms to adopt imported foreign equipment instead of efficiency improvement under the given technological conditions. Several studies have found that TFP growth in China has been achieved more through technical progress than through efficiency improvement (Zheng & Hu, 2006; Zheng, Liu, & Bigsten 2003). Since efficiency remains low, there are still large unexplored possibilities for efficiency improvement in China.

(ii) *The market has its limits*

On the other hand, it has often been taken for granted that economic reforms aiming at establishing a market system with private ownership will automatically boost efficient production and promote technological progress including innovations. But it is important to understand that the establishment of market, ownership reform, foreign direct investment, and trade will only improve the situation under which Chinese firms operate to a certain extent.

One school of thought on the interpretation of Chinese reform is that China has achieved the greatest success in precisely the areas where market reforms have gone the furthest (Sachs & Woo, 2000). However, this may not apply in certain areas. For example, as in the East Asian NICs, one of the key ingredients of China's reform strategy has been export orientation. The policy has led to rapid expansion of the output of labor-intensive and low value-added production, seems to be consistent with China's comparative advantages. Consequently, more than 60% of industrial exports were from foreign-invested enterprise, a substantial fraction of the remainder of the country's exports consists of industrial products that are either original equipment manufacturers (OEMs), or low value-added, low technology, non-branded goods for multinationals (Nolan, 2005). China's comparative advantage has been exploited to the extent that the export oriented strategy has become a major cause of imbalance in the macro economy.

Chinese firms spend small amounts on research and development. There are still many state firms that are subject to systematic state intervention according to Nolan (2005). He points out that although the 14 Chinese firms in the Fortune 500 are state firms, they are not really internationally competitive without government protection. An issue often discussed in China is that China has none among the top 100 brands in the world, and indigenous Chinese firms are completely outside the world's top 700 firms in terms of R&D spending, while multinationals are setting up their research and development laboratories in China.

There have been policy miscalculations in the areas of health care, education, and housing. On the one hand, "the transition from planned to market economy has involved a massive shift of financial risk from state-owned enterprises to households, thereby creating a large perceived need for precautionary saving by households to fund anticipated retirement, medical, and educational expenses" (Kroeber, 2005). High saving has also become a major source of imbalance in the macro economy.

On the other hand, market oriented reforms in health care and education have resulted in rocketing treatment charges and tuition fees, chronic corruption, and deteriorating quality in teaching and medical service. Taking education as an example, a typical Chinese planner would think education is good for growth and productivity; it would be hard to believe that sustained productivity improvements can be achieved without an educated population. But the rapid growth of China's universities since 1999 has resulted in lower teaching standards and reduced quality. In 1999, the government expanded its higher education program, and university enrollment increased by 48% from the previous year. Though the expansion has allowed more high school graduates to enter the universities, poor teaching methods and lack of financial resources has meant that the quality of the education is often low. Only 2,000 yuan (250 US$) on average is allocated to each undergraduate nowadays in comparison with 6,000 yuan before the expansion (People's Daily, 2007). Perhaps the inefficiencies of the educational system explains why Holz (2005b) found a negative relationship between education and output using Chinese aggregate time series data.

(iii) *Policy change may only bring level effects*

Economists often point out that the most important component of China's growth is the immense productivity gain arising from the shift of labor from low-productivity agriculture to higher-productivity services and industry. While this type of policies has been successful in promoting growth and productivity for a sustained period, the limitations of such policies were not properly understood among policy analysts. Some policies that aimed at alleviating past distortions from the planning period had only one-time level effect. For example, when the TVEs development, which transferred more than 120 million people out of agriculture, had been exhausted in the early 1990s.[9] Although the reallocation of labor from low-productivity to high-productivity activities would continue to contribute to economic growth, Kuijs and Wang (2006) find that since the early 1990s the shift of labor from low-productivity agriculture has been limited, and hence contributed only marginally to overall labor productivity growth. Moreover, a recent reversal in the policy of promoting urbanization was signaled by the government's call for the construction of the new socialist countryside, indicating an intended slowdown in the urbanization process in the near future.

(b) *Stabilization policy*

A series of imbalances in the macro economy have to be dealt with if China is to raise TFP growth. There have been many discussions about what policy adjustments are currently needed. Blanchard and Giavazzi (2006) recommend a three-handed strategy. This entails a decrease in saving (particularly private saving), an increase in the supply of services (particularly health services), and an appreciation of the RMB. Dunaway and Prasad (2006) point out that this discussion runs the risk; however, of prompting a string of ad hoc policy actions that could provide temporary relief, but no lasting solution to fundamental imbalances in the Chinese economy. They argue instead that the real issue in China is how to rebalance the economy away from heavy dependence on exports toward domestic demand, including a substantial improvement in the efficiency of investment. They note that, as companies have improved their performance, corporate saving has risen and now accounts for almost half of national saving. Corporations tend to keep their profits to finance their own investment because private firms often have limited access to bank loans and state firms are not obliged to pay dividends to the government. Generally speaking, the system provides few alternatives for raising money to the extent that Chinese firms have to finance their reproduction with retained profits. In addition, Chinese households have strong precautionary motive for saving due to demographic factors. They saved almost a third of their disposable income in recent years according to some estimates.

China needs to encourage more consumption, but this can only take place gradually since precautionary savings are well motivated; and there are also forced corporate savings due to the under-development of financial intermediations. The slow development in the financial sector in China has led to limited availability of credit, so that households usually have to save in order to purchase consumer durables. Since there are not many alternatives to saving in state-owned banks and it has also resulted in limited opportunities for portfolio diversification and low returns on households' financial assets, financial market reform and development is thus a key priority, which the Chinese authorities recognize (Dunaway & Prasad, 2006).

Moreover, Rodrik (2006) notes that China's export is more technology intensive than one would assume given its factor endowments. He argues, however, that the country has *via* its industrial policy managed to shift its export structure in this direction. In other words, the government has been willing to support investments that are more sophisticated than what its comparative advantages would typically support and what the market left to itself would generate. And he further points out that once one successful firm can be established in a new type of production it tends to be followed by others. Once investors in a country "discover" a number of high-productivity exportables, this has a powerful demonstration effect. Such an investment strategy may have static inefficiency costs, but he argues that it is an essential force behind the rapid Chinese growth. This proposition has not been properly investigated yet, but this is something that needs to be looked into in greater detail.

China currently seems to attempt to preserve an undervalued currency as an export promotion measure. One would assume that an undervalued exchange rate reduces the pressure for technical upgrading of production structures. However, Guillaumont, Jeanneney, and Hua (2003) get mixed results. They find that appreciation of the real exchange rate in China has had an unfavorable effect on technical progress, but a favorable effect on efficiency growth, and that these two effects partially offset each other to give a small negative effect on productivity growth. More efforts are needed to further investigate the issue.

Overall, China's investment patterns are grossly imbalanced. The service sector is underdeveloped, accounting for only 40% of GDP; and the agriculture sector gets only 2% of investment. Capital productivity is low due to this imbalanced investment pattern and inefficiencies in the financial sector. It does not necessarily mean that the country overall may have low return on investment. Investment in human capital and in the service sector may have very high returns.[10]

Policies should stress more on the need to further reform the fiscal policy which is quite regressive, and the banking and financial systems which are highly inefficient. The investment pattern needs to be re-balanced across sectors. The government should get out of "export promotion" and industrial policy-type of interventions, but concentrate on providing public goods and services such as improving rural education and health services and protect the environment. In other words, China does not need more growth, but more pro-poor/equitable and high quality growth.

(c) *Environmental constraints*

One may expect that TFP grows fast when the economy grows rapidly. However, both estimates of GDP and TFP growth would be lower if environmental costs were taken into account. For example, policies, which encourage mining, may do little to promote development, when account is taken of the environmental degradation and resource depletion (Stiglitz, 2001).

The Chinese government has been working on criteria and indexes of a green GDP, which deducts the cost of environmental damage and resources consumption from the traditional gross domestic product (People's Daily, 2004). Preliminary results in the recently issued Green GDP Accounting Study Report, 2004, suggest that economic losses due to environmental pollution reach 512 billion yuan, corresponding to 3.05% of GDP in 2004, while imputed treatment cost is 287 billion yuan, corresponding to 1.80% of GDP (GOV, 2006). Although the concept of and measurement for green GDP are rather controversial, the report may serve as a wakeup call to the government's strategy of growth at all costs.

From a productivity analysis perspective, the concept of green GDP can be straightforwardly extended to TFP, that is, green TFP. A slower green TFP growth may imply a slower (green) GDP growth.

6. CONCLUDING REMARKS

China has had one wave of reform after another with short-run gains in productivity. Structural reforms with longer-run effects have been delayed in the process. China's growth strategy since the mid-1990s has emphasized capital formation at the expense of efficient allocation and utilization of production factors, which has led to a slowdown in TFP growth. Ironically China's recent capital-intensive growth resembles the Soviet Union's, which China has tried to avoid during its nearly thirty years of economic reform and opening up to the outside world. The Soviet Union only managed GNP growth of 4–5% per year (Perkins, 1988), while China's GDP has been 8–9% and its economy is much more open. To many international commentators China looks more like the East Asian tigers.[11] But in fact both the Soviet Union and the East Asian NICs applied the model of unlimited labor-supply, since both emphasized saving and investment strongly (Sachs, 2004).

To achieve continued high GDP growth China will in the longer term have to rely more on TFP growth and less on capital deepening than in recent years. According to the recently released 11th five-year plan, the government recognizes that long term economic growth will be depending on science and technology, which in turn rely on government policies toward research and development including entrepreneurial activity, and the establishment of market-based institutions.

Non-market institutional development is also required to complete China's move to a market economy with sustained productivity growth. "Igniting economic growth" generally requires a limited range of reforms that need not overly tax non-market institutions, but sustaining it is "in many ways harder" (Rodrik, 2003). Conventional development strategy emphasized the importance of increasing capital and reducing economic distortions. "But development represents a far more fundamental transformation of society, including a change in preferences and attitudes, an acceptance of change and an abandonment of many traditional ways of thinking" (Stiglitz, 2002). So many economic and social problems remain to be addressed if China is to achieve the transformation from extensive to intensive growth that is necessary to sustain growth in the long run.

NOTES

1. Shan (2006) discusses China's low-profit growth model and puts China in the same category as the East Asian NICs. He argues that their miracle was produced much more by increases in inputs than productivity gains, citing the works of Young, Lau, and Krugman. Kuijs and Wang (2005) use a growth accounting framework to decompose the sources of labor productivity growth and find that growth of industrial production, led by a massive investment effort that boosted the capital/labor ratio, has been the single most important factor driving GDP and overall labor productivity growth since the early 1990s. Liang and Yi (2005) find that a sharp and sustained increase in productivity has been the driving force behind China's growth. And Liang (2006) went on to argue that the so-called "over-investment" problem in China reflects data quality issues, rather than a true state of affair and the return on investment in China has been high and rising since the turn of the century, due to substantial efficiency gains in the larger economy and at the corporate level. Liang therefore believed that the investment "boom" in China was fundamentally justified and not doomed for a bust. Garnaut (2005) also discussed the sustainability of China's growth from a more general perspective.

2. There is also another reason that we are interested in linking TFP growth to the currently overheating Chinese economy. TFP is not only important for long run growth, but also for shorter period concerns. Simulation studies of business cycles of both industrialized and less developed countries indicate that TFP is very important for understanding period of depression and prosperity. Examples are Japan's lost decade of growth in the 1990s (Hayashi & Prescott, 2002), Argentina's great depression in the 1980s (Kydland & Zarazaga, 2002), and Ireland's booms and busts during the four decades up to 1990s (Ahearne, Kydland, & Wynne, 2005). China would be another interesting case for business cycle studies from a productivity perspective.

3. New results at both regional and national levels suggest that factor productivity showed a sharp increase in the early 1980s, entered a period of stagnation or flux in the late 1980s followed by another period of productivity growth and slowdown in the 1990s (Mead, 2003). Fan and Zhang (2002) found that the official data overstated the impact of rural reforms on both production and productivity, but both production and productivity still grew at respectable rates during the reform period (see also Xu, 1999).

4. Recently revised GDP statistics are used. See Appendix for a description of data.

5. A test of structural breaks is reported in Table A2, Appendix A.

6. The Standard and Poor's rating agency recently estimated that China's banks have issued about $650 billion in bad loans, or about 40% of outstanding loans (Wolf, 2005).

7. The spending patterns of Chinese firms are quite different from that of Asian countries such as South Korea and Japan. In the 1970s and 1980s industrial firms in those countries spent two to three times the purchase price of foreign equipment to digest the technology (Gilboy, 2004).

8. It is still not very clear how the assumption of increasing TFP's contributions to growth found its way into these forecasts, while recent economic studies rather predict either slowdown in TFP growth or reported unsatisfactory performance by Chinese firms in technology absorption and innovation.

9. Kung and Lin (2007) provide a detailed account and analysis of the decline of TVEs.

10. We thank an anonymous referee for pointing this out.

11. We saw above that China's TFP growth slowed since the mid-1990s, but over the whole reform-period it has been rising at 2–3% per year, actually faster than the East Asian tigers at the same stage of development; during 1960–84 their TFP growth averaged only 1% (Economist, May 2004). This may be explained by the fact that China has had access to a more advanced stock of world knowledge available at modest cost to enhance production.

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APPENDIX A. EXTENSIVE GROWTH, GROWTH ACCOUNTING, AND TREND TFP

This appendix explains the methodologies involved in the study.

A.1. *Extensive growth*

Extensive growth is a growth strategy relying on the expansion of inputs. "As capital accumulation and growth of the labor force raise the growth rate of aggregate output, due to diminishing returns these growth effects are without a lasting effect on *per capita* income" (Irmen, 2005). A key feature of the extensive growth model is that capital grows faster than GDP. This is due to the high growth rate of capital and low-productivity advance. Consequently, in order to sustain the growth rate of capital, the share of investment in GNP, in constant prices, must grow continuously. The share in current prices can move in both directions, depending on the change in the relative price of investment goods *vis-à-vis* other GNP uses (Ofer, 1987). Specifically, the relation between I

(investment), K (the capital stock), and Y (national product) in real terms can be written as follows:

$$I/K = (I/Y)(Y/K).$$

Notice that the growth accounting formula is given by $\dot{Y} = \dot{A} + \alpha\dot{K} + \beta\dot{L}$, where $(\cdot)$ denotes growth rates, L is labor, and A is the level of technology. Given growth rate in labor input and the rate of technological progress, sustainable growth in Y will have to be backed up by sustainable growth in K. When growth is deemed intensive, $\dot{K} < \dot{Y}$ so Y/K increases over time. In order for $I/K(=\dot{K})$ to keep constant I/Y need to be reduced, that is, $\dot{I} < \dot{Y}$. In other words gross capital formation rate does not have to rise to sustain a given growth rate in output, which is feasible.

When growth is considered as extensive $\dot{K} > \dot{Y}$, then Y/K goes done and a constant I/K requires a increasing I/Y, which is not sustainable in the long run. Moreover, the share of investment in GNP in current prices may be written as $I_C/K_C = IP_I/YP_Y$, where C stands for "in current prices" and P for "price level." A decrease in the relative price of I due to rapid technological change may reduce the increase of I/Y in real terms.

A.2. *Growth accounting*

The basic statistics we examine in the study came from growth accounting. Given a production function of the following form:

$$Y_t = AK_t^{\alpha}N_t^{1-\alpha},$$

where Y stands for output, K capital stock, and N quality adjusted labor. $N = LH$, where L is labor and H is human capital or labor quality in terms of average years of schooling. A and α are Solow residual and output elasticity of capital, respectively. The production function after some mathematical manipulation can be used to derive the growth accounting formulae as follows:

$$\dot{Y} = \dot{A} + \alpha\dot{K} + (1-\alpha)\dot{N},$$

where $(\cdot)$ denotes growth rates in continuous time, which can be approximated either with annual percentage change or first difference of log level variables. Annual percentage changes are used in Table 2 to be consistent with the GDP growth index in the statistical yearbook, but log differences are applied in H–P filtering for the sake of convenience. The difference between the two approximations is minor at the observed magnitude of annual changes. In order to use the formulae, one needs to know exactly how large α is. Most aggregate production function estimations for China obtained capital elasticity of more than 0.5. Examples are Chow (2008), Chow and Li (2002), Chow and Lin (2002), and OECD (2005). A summary of the estimates is presented in Table A.1. Our own estimate based on vector error-correction models (VEC) ranges from 0.726 to 0.842, which seems high.

An alternative way to obtain α is to use factor shares in place of output elasticities of inputs. This amounts to assuming profit maximization under the condition of constant returns to scale and perfect competition in both inputs and output markets. The resulting input index is traditionally known as Divisia Index. This means that using factor shares as weights for aggregating inputs impose strong institutional as well as economic assumptions.

A summary of labor's share is available in Hu and Khan (1997). Seldom labor's share exceeds 0.5, which is consistent with the capital elasticity estimates from most aggregate production function studies. The study by Li et al. (1993) gives higher estimates for labor's share because it included implicit housing subsidies (state-controlled rent) in labor compensation.

According to OECD (2005), the capital share in GDP had averaged 0.40 during 1978–2002, indicating perhaps an increasing trend in labor share. This phenomenon was also reported in Young (2003). Liang and Yi (2005) reported an average 0.4 for capital share, and even used a share of 0.31 from Lin, Guo, Li, Sun, and Wang (2003). However, a capital share of 0.53 was still preferred in the OCED study since they felt that the estimate was closer to the expected value than in the papers cited in their study where capital stock coefficients of 0.65 and higher had been found. They argue that the estimate is, for example, markedly lower than that found in the Chinese Academy of Social Sciences' quarterly economic model, where the capital coefficient is set at 0.85 (He, Wu, Liu, & Wang, 2004). They believe that the lower, and more realistic estimate of the coefficient on capital, may be the reason why the estimates of TFP shown in their study are higher than those they have cited.

Therefore, a capital share of 0.5 seems to be a safe number to be used for the current analysis. On the one hand it is not as high as the capital elasticity obtained from the aggregate production function estimations such as in Chow and Li (2002), on the other hand it is still sensitive enough to capture the slowdown in TFP growth in the last decade or so. We thus followed Wang and Yao (2003), Kuijs and Wang (2006), and Kuijs (2006) taking a capital elasticity of 0.5 for our study. Wang and Yao also checked the sensitivity of their TFP estimates to a range of factor shares, for example, from 0.33 to 0.67 for capital. Their results show that TFP estimates are not very sensitive to the choice of capital shares ranging from 0.40 to 0.6. In our study, what appears to be more certain is

Table A.1. *Output elasticity of capital in the Chinese aggregate economy*[a]

Studies	Data period	Estimates	Functional forms
Chow (2008)	1952–2005	0.601	Cobb–Douglas (CD)
OECD (2005)	1978–2003	0.526	CD (ARIMA, H–P filtering)
Guo and Jia (2005)	1978–2004	0.692	CD
Heytens and Zebregs (2003)	1970–98	0.643	CD
Chow and Li (2002)	1952–98	0.628	CD
Chow and Lin (2002)	1952–98	0.647	CD
Wang and Meng (2001)	1953–97	0.433	CD
Chow (1993)	1952–88	0.538–0.640	CD with a positive time trend
Lau and Brada (1990)	1953–85	0.422	Deterministic translog at sample mean
Chow (1988)	1952–84	0.602	CD
Our own estimates (2005)	Chow and Li (2002)	0.726–0.842	CD with vector error-correction estimation

[a] All results assume constant returns to scale.

that China's aggregate productivity performance measures since the early 1990s have become rather sensitive to the choice of capital shares. To check the robustness of our observation, we compare the TFP estimates in Figure A.1 with capital elasticities chosen at 0.4, 0.5, and 0.6. Figures A.1 and A.2 compare different TFP series.

A.3. *H–P filtering*

The following method has been used to derive Solow residual in Njuguna, Karingi, and Kimenyi (2005) and Hong Kong Monetary Authority (2001). Total factor productivity (TFP) can also be measured as H–P filtered Solow residual to take account the influence of business cycles. The production function assumes the standard Cobb–Douglas form as follows:

$$Y_t = AK_t^{\alpha}N_t^{1-\alpha},$$

where A is the Solow residual, it is obtained as follows:

$$\ln A = \ln Y_t - (\alpha \ln K_t + (1-\alpha)\ln N_t).$$

Following French (2001), $\ln A$ consists of two parts, one is its trend component, and the other the cyclical component. It can be derived as follows:

- Output Y is the product of trend Y_{trend} and gap Y_{cycle}.
- Employment L is the product of trend employment L_{trend} and a stationary cycle term L_{cycle}.
- Quality adjusted trend employment N_{trend} is the product of L_{trend} and human capital H.

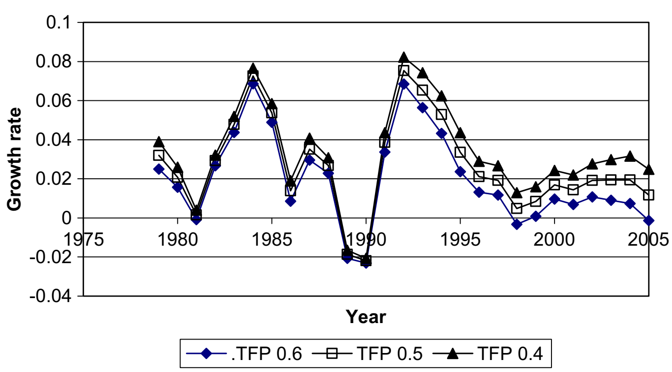

Figure A.1. *Comparison of Solow residuals with different capital elasticities (0.4, 0.5, and 0.6). Labor measure is adjusted for changes in labor quality.*

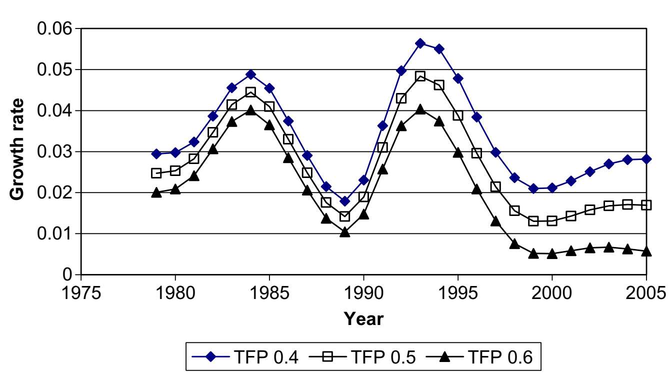

Figure A.2. *Comparison of H–P filtered TFP growth series with capital elasticity chosen at 0.4, 0.5, and 0.6. Labor measure is adjusted for change in labor quality. These H–P estimates correspond to a smoothing parameter of 6.25 recommended in Ravn and Uhlig (2002).*

- A two-factor Cobb–Douglas production function holds in equilibrium, human capital is taken to be exogenous, and the capital stock is assumed given.
- The Solow residual A includes cyclical factors as well as trend in total factor productivity $\text{TFP}_{\text{trend}}$.

These five definitions are expressed as follows:

$$Y = Y_{\text{trend}} * Y_{\text{cycle}}, \quad (1)$$

$$L = L_{\text{trend}} * L_{\text{cycle}}, \quad (2)$$

$$N_{\text{trend}} = L_{\text{trend}} * H, \quad (3)$$

$$Y_{\text{trend}} = \text{TFP}_{\text{trend}} * K^{\alpha} * N_{\text{trend}}^{1-\alpha}, \quad (4)$$

$$Y = A * K^{\alpha}(L * H)^{1-\alpha}. \quad (4a)$$

The observed Solow residual is calculated by inverting Eqn. (4a). Eqns. (1)–(4), (4a) imply the following relationship between the observed Solow residual and the underlying trend in total factor productivity:

$$\ln A = \ln\left[Y_{\text{cycle}}/L_{\text{cycle}}^{1-\alpha}\right] + \ln \text{TFP}_{\text{trend}}. \quad (5)$$

The objective of H–P filtering is to extract $\text{TFP}_{\text{trend}}$, the unobserved trend in total factor productivity is shown in Eqn. (5), from the Solow residual. Human capital does not play a role in the de-trending, so Eqn. (5) is also valid for employment measures not adjusted for labor quality.

Given a time series y_t is the sum of a growth component y_t^{trend} and a cyclical component y_t^{cycle}, the Hodrick and Prescott (1997) filter is obtained by solving the minimization problem:

$$\underset{\{y_t^{\text{trend}}\}_{t=-1}^{T}}{Min} \left\{ \sum_{t=1}^{T} \left(y_t - y_t^{\text{trend}}\right)^2 + \lambda \sum_{t=1}^{T} \left[\left(y_t^{\text{trend}} - y_{t-1}^{\text{trend}}\right) - \left(y_{t-1}^{\text{trend}} - y_{t-2}^{\text{trend}}\right)\right]^2 \right\},$$

where the parameter λ is a positive number which penalizes variability in the growth component series. If $\lambda = 0$ then the filtered series is the original series, that is, there is no smoothing. Hodrick and Prescott recommend using $\lambda = 1{,}600$ for quarterly data. This filter is implemented as part of PROC EXPAND in SAS (Cheah, 2006). For annual data, Ravn and Uhlig (2002) recommend using $\lambda = 6.25$ for annual data and $\lambda = 129{,}600$ for monthly data. The resulting series with labor adjusted for quality are presented for different capital elasticities in Figure A.2. A simple test of structural breaks was attempted in Table A.2, which shows that the null hypothesis of no structural breaks was rejected.

However, a more serious test of structural beaks can be complicated. The H–P filtered trend cannot capture structural breaks (Andersen, 2002). Schlicht (2007) proposes a method

Table A.2. *Test of structural breaks in china's growth pattern with quality adjusted labor (1978–2005)*

	$\text{TFP}^{0.4**}$	$\text{TFP}^{0.5***}$	$\text{TFP}^{0.6***}$
1978–95	0.038	0.033	0.028
	(0.012)	(0.011)	(0.010)
1995–2005	0.028	0.019	0.010
	(0.008)	(0.008)	(0.008)

Note: (1) $\text{TFP}^{0.4}$ refers to the estimates using 0.4 as capital share, and so on so forth and (2) figures in parentheses are standard errors.
** It indicates the rejection of the null that the means for the two period are not different at the 5% level of significance.
*** It indicates the rejection of the null that the means for the two periods are not different at the 1% level of significance.

for coping with this problem. Boone and Hall (1999) developed a method to decompose time series based on the stochastic trend model that was demonstrated to be more reliable and robust in the presence of structural breaks using Monte Carlo techniques. Pelaez (2004) dated the productivity slowdown in the industrialized countries with a structural time series model and found that the slowdown started in the mid-1960s.

APPENDIX B. DATA DESCRIPTION

The main variables investigated in the study are aggregate output (GDP at constant price), aggregate labor (number of people employed), and capital stock (accumulated fixed capital investment at constant price). Although the purpose of our data work was basically to update the main variables for a few years based on other studies, each of the variables involved some complications. Several authors have criticized China's GDP estimates, but we chose to use the official figures from the recently updated nominal GDP and GDP series for 1993–2005. This represented an increase by 16% of the 2004 GDP over the old statistic. The major problem with the labor force series was a huge jump in the 1990 figure, which registered a 17% increase in the labor force in comparison with 1989, besides some other problems. Capital stock was the most problematic, but we basically followed Kuijs (2006), who based his estimates on Wang and Yao (2003).

B.1. *Real GDP*

The most recent study on China's reform period economic growth figures is Holz (2006), who discards Maddison's 1998 OECD study in favor of the official data. Maddison's adjusted GDP growth figures give an average annual real GDP growth rate of 7.49% during 1978–95, which contrasts the official statistics of 9.88%.

Data problems were also discussed in Holz (2004) with special attention to GDP statistics as the aggregate measure of productive activities in China. We noted the arguments of Holz (2004, 2006) and used the official statistics for the aggregate measure of output. GDP figures from 1977 to 1992 were taken from Wang and Yao (2003), while the recently revised GDP figures were used for 1993 to 2005.

We first take the year-on-year GDP growth index from the statistics yearbook to derive a GDP deflator. The year-on-year GDP growth index, GDPI, is defined as follows:

$$\mathrm{GDPI}_t = (\mathrm{GDP}_t/P_t)/\mathrm{GDP}_{t-1},$$

where GDP refers to nominal GDP, and P_t is the year-on-year GDP deflator to make GDP between two successive years comparable with the first year as base year. Thus, the year-on-year GDP deflator can be expressed in terms of nominal GDP at t and $t-1$ and year-on-year GDP growth index:

$$\mathrm{P}_t = \mathrm{GDP}_t/(\mathrm{GDP}_{t-1}\cdot \mathrm{GDPI}_t).$$

Then the GDP deflator at time t is just the accumulative multiplication of the previous year-on-year deflators up to time t with 1995 as the base year:

$$(\text{GDP deflator})_t = \prod_{t=1978}^{t} P\Bigg|_{P_{1995}=1}.$$

Real GDP is obtained by dividing nominal GDP by the GDP deflator:

$$\mathrm{RGDP}_t = \mathrm{GDP}_t/(\text{GDP deflator})_t.$$

B.2 *Labor*

A major change in the registry in 1990 and subsequent layoff of state workers made the employment statistics before and after 1990 inconsistent. This problem was not present in Table D3, Maddison (1998), but he notes, "The 1997 Yearbook give a total for the years 1990 onwards which is bigger than the sum of the sectors, and differs from the total in previous yearbooks. There seems to be some sort of error in the new official total." (cited in Holz (2006, p. 172)). Holz took the matter more seriously, he reported that the Statistical Yearbook 1997 and in all later editions, the NBS retrospective revised total employment of 1990 upward by 14.12%, and similarly for later years, without, however, attributing this increase in employment to individual industrial sectors (agriculture, industry, construction, *etc*.). However, with the Yearbook 2005 (CSY, 2005), which we use, the increase in the employment from 1990 was also distributed to the different sectors.

While the labor force of society is no longer reported as the official aggregate employment series, these data continue to be collected and can be inferred from the detailed tabulations of the CSY. Young used these data to extend the "old" series to 1998, as reported in Table 5 of his study. However, he was not able to avoid a further discontinuity, introduced in 1998, when the definition of workers in urban enterprises was revised to include only those actually working and receiving income (as opposed to those who retained employment contracts, without actually working in the unit). This resulted in a substantial reduction in the estimated working population, particularly in manufacturing.

In our study, we used an old series for employment of 1990–95 in World Bank (1997, Table 30), so the growth rate in employment in 1990 was taken from this old data series for time plot and estimate of TFP by year. We then assume that the understatement of employment has been constant over time prior to 1990 to impute the number of employed people before 1990 (Herd & Dougherty, 2007). This allows us to compute labor productivity for the entire period as real GDP per employed person (quality adjusted).

B.3 *Capital stock*

For the 1977–99 period, we used capital stock data taken from Wang and Yao (2003). To update to 2005, total fixed asset investment figures came from Statistical Yearbook 2005 for 2000–04 period (CSY, 2005). 2005 statistics on total social fixed asset investment and price index were from the Abstract of China Statistics 2006. We set 1995 as the base year to be consistent with the investment deflator in Wang and Yao (2003). The depreciation rate is 5% as in Wang and Yao (2003). So the capital stock during 2000–05 was updated as follows:

$$K_t = K_{t-1}(1-\delta) + I_t,$$

where K stands for capital stock, δ represents depreciation rate, and I is investment. Our resulting capital stock series is not exactly like the one presented in Liang (2006) due to differences in choosing investment measures and depreciation rates. Wang and Yao (2003) used total social fixed asset investment to measure gross fixed capital formation at current prices, while the series from Liang (2006), which seemed to be based on Liang and Yi (2005), took investment figures from the GDP tables of the expenditure approach to national account. Wang and Yao (2003) assumed a 5% depreciation rate for capital, while Liang (2006) took the number as 4%. But the rapid growth in capital stock in recent years was captured in both series. In 2004, both series show that growth in capital stock was close to 15%, and a year later growth rate exceeded 15%.

B.4. *Human capital*

To measure human capital, we use average years of schooling of Chinese laborers to make adjustment for labor quality improvement. Data from 1978 to 2005 are taken from Holz (2005a). There are two series available, one without military, the other with military. We took the series of average level of schooling of laborers with military. Labor is defined as quality adjusted laborers, that is, number of employment multiplied by average years of schooling.