Ownership, R&D and Productivity Change:
Assessing the Catch-up in China's High-tech Industries

Junbo Yu* and Peter Nijkamp
Dept. of Spatial Economics, VU University Amsterdam
The Netherlands

Abstract

This study contributes to the debate on whether China's domestic enterprises (DEs) have experienced a significant catch-up compared with foreign-funded enterprises (FFEs) in high-tech industries. Our paper tries to estimate a new set of capital stock and R&D capital stock by ownership for China's high-tech industries. Then, using this newly constructed data set, it assesses the comparative productivity performance of state-owned enterprises (SOEs) (as the most important proxy for DEs) in high-tech industries from 1996 to 2006. The results show that SOEs as a whole have experienced an inverted U-shape trajectory of catch-up for 1996-2006, while those SOEs which originate from competitive industries tend to show a better performance. With respect to the technology catch-up, SOEs in particular are still lagging behind because of their failure to develop indigenous technology capabilities.

JEL classification: E22; L63; O47; P27

Keywords: Productivity; R&D; Catch-up; Indigenous technology capability

pn286jy

* Corresponding author: Junbo Yu, Dept. of Spatial Economics, VU University, De Boelelaan 1105, 1081 HV Amsterdam, the Netherlands. Email: jumboyu@gmail.com

1 Introduction

The dramatic rise of China's high-tech industries[1] since the mid-1990s has been queried by critics because of its stagnation in the lower end of the value chain[2] and its excessive reliance on foreign-funded enterprises (FFEs) (Gilboy, 2004; Ning, 2007). The opposition, however, contends that persistent marketization and China's government-led industrial policy, which aimed to construct globally-competitive companies by vertically integrating and reforming state-owned enterprises (SOEs), have already reduced the technology gap between domestic enterprises (DEs) and FFEs (Jefferson, 2005) and will further accelerate the catch-up process with farsighted initiatives such as the Independent Innovation Strategy (IIS) (OECD, 2007). Unfortunately, up to this point, neither sides in this debate has been able to justify their assertions with well-defined and widely accepted indicators to measure the gap between DEs and FFEs, let alone to summarize the dynamics of this gap as solid empirical evidence.

This paper attempts to contribute to this debate by conducting a comparative productivity analysis of SOEs which dominates other DEs in nearly all aspects in high-tech industries (NBS, 2002, 2007b), and FFEs. A portfolio of conventional productivity measurements, as well as some novel ones, will be adopted and calculated to evaluate the overall catch-up performance of SOEs. Our results, in general, reveal an inverted U-shape curve across different productivity measurements in terms of the catch-up performance of the SOEs from 1996 to 2006. Such unfavourable facts cast doubt on the efficacy of China's current industrial policy which aims to achieve technological pre-eminence by favouring SOEs as the backbone.

The remainder of this paper is organized as follows: Section 2 briefly reviews the development of China's high-tech industries and the divergent assessments of it as found in the recent literature. Section 3 explains the rationale of conducting a productivity analysis to evaluate the DEs' catch-up performance and addresses several technical problems, particularly looking into the estimation of capital stock and research and development (R&D) capital stock. Section 4 reports the results of our estimations and calculations, followed by a discussion on their policy implications. Section 5 concludes the analysis of this paper.

---

[1] The definition of high-tech industries in China is the same as in OECD countries (Table 1). However, this definition and associated industrial statistics only came into being after 1994, when the most recent adjustment took place in the Chinese industrial classification (IC) system so as to better comply with the ISIC. Therefore, official statistics about China's high-tech industries under the current IC system have only been available since 1995.

[2] Hence, China's high-tech industries have been mostly those concerned with processing and assembling imported critical components.

2 Elements of China's High-Tech Industries Development

China's persistent struggle to achieve rapid and sustained economic growth has been made conspicuous by the critical role attached to the modernization of science and technology, ever since the 1950s when the Communist Party of China (CPC) proclaimed "the love of science" to be a national virtue. By the onset of the Cultural Revolution, China's emerging science and technology (S&T) system, while still modest in scope, began to produce some promising results. In 1964, for instance, the Chinese trial-produced an electronic computer (second-generation) and successfully tested an atomic bomb (Simon, 1989). Unfortunately, the subsequent launching of the Cultural Revolution in 1965 became a major setback for Chinese S&T. The efforts by Mao and later the "gang of four" (*Si Ren Bang*) to promote science and technology through reliance on the "mass line" (*Qunzhong Luxian*), as opposed to an elite core of qualified personnel, led to a dismantling of the infrastructure that had been built up over a decade. Meanwhile, the computer and electronics revolution began in the industrialized world during the late 1960s and early 1970s. As a consequence, the technology gap which had been diminishing between China and the developed countries widened again. More devastatingly, China lost almost a complete generation of scientific and technical personnel as a result of the closure of most universities and research institutes in the Cultural Revolution (Deng and Treiman, 1997).

China's post-Mao experience: namely, three decades of reform and opening-up, has witnessed a development strategy in the high-tech industries (Table 1) which could be simplified as "walking with two legs" (Yao, 2006)—the first "leg" is relying on imports of foreign technologies, including direct imports and foreign direct investment (FDI); the other "leg", in contrast, is fostering domestic research and innovation through the synergetic effect among universities, research institutes and industries (Simon, 1989; Story, 2005). Ideally, a well-coordinated, balanced and combined movement of these two "legs" will allow China's high-tech industries to benefit not only from international technology transfer and spillovers but also from indigenized innovation favoured by the government.

[Insert Table 1 Here]

In spite of China's soaring volume of high-tech exports, some observers viewed the foregoing "two legs" strategy as vain talk and pointed out that China's technology catch-up was actually crippled by the severe dependency on imported technology. By stressing that foreign firms are still claiming the lion's share of China's R&D investment, as well as of exports from the high-tech industries, while its domestic technology leader, the SOEs, are severely addicted to imported technologies, Gilboy (2004) depicted the Chinese high-tech industry structure as one composed of inefficient yet powerful SOEs, increasingly dominant FFEs, and a private sector that is unable to compete with others on equal terms. In addition, from an institutional perspective, Gilboy has generalized China's "industrial strategic culture", which is distorted by its unreformed political system, as an encouragement to seek short-term profit, local autonomy, and excessive diversification. This "culture" tends to chronically jeopardize networking efforts among firms, industries and research institutes, to deny investment in long-term technology development and diffusion, and to indulge inefficiency and technological dependency with local protectionism and particularism, which together will prevent DEs in high-tech industries from catching up with their foreign-funded competitors.

Ning (2007) further complemented Gilboy's proposition by showing that China's most competitive high-tech export industry, the information and communication technology (ICT) sector, has mainly been processing imported materials and applying mature, standardized and peripheral technology, while most value-added content is created elsewhere in the world. What is more frustrating, even this low value-added high-tech sector has also been more and more dominated by FFEs in terms of sales, profits, exports and new products generation. Therefore, Ning concluded that the Chinese government's attempt to build globally-competitive larger ICT firms by reforming SOEs is falling short of its goal.

In contrast, Jefferson (2005) argued that overuse of the share in total high-tech products export as an indicator to compare the performance of SOEs and FFEs tended to ignore the more subtle story of China's technological transformation, where more labour-using and capital- and energy-saving innovations have been produced. By exploiting a firm-level data set which was based on surveys of large- and medium-sized enterprises (LMEs), Jefferson revealed that Gilboy had significantly underestimated the DEs' technological catch-up effort in terms of R&D investment[3]. Moreover, Jefferson refuted Gilboy's assertion with additional national-level data: first, the national R&D intensity (the ratios of R&D expenditure as a percentage of GDP) of China had rapidly climbed to 1.3 percent in 2003, substantially greater than what would be expected given the country's level of per capita income; second, the preceding surge in China's R&D intensity had resulted from the boom in enterprise-financed R&D rather than from government funding, indicating a more market-oriented and commercialized innovation structure. Accordingly, his conclusion is that R&D has become extensively and deeply embedded in, but not limited to, China's high-tech industries and has thus enabled the country to experience S&T take-off. Later on, more of the literature supported Jefferson's judgment with updated descriptive data (Chen and Shi, 2005; OECD, 2006, 2007), as well as some in-depth case studies centring on selected high-tech industries (Fan, 2006; Jin and Zedtwitz, 2008).

While the efficacy of the "two leg" strategy was still in dispute, new initiatives had already been endorsed by the Chinese government to raise the original expectation of the catch-up effort: namely, to build an innovative country[4]. Not surprisingly, the newly

[3] Jefferson (2005) calculated that, from 1995 to 2001, China's domestic LME's R&D intensity (R&D expenditure as a percentage of value added) had reached 3.3 percent, instead of the mere 1 percent reported by Gilboy.

[4] In February 2006, the Chinese State Council issued the "National Guidelines on a Medium- and Long-term Program for Science and Technology Development 2006-2020" (hereafter, "S&T Guideline"). Along with more innovation assessment indicators such as the numbers of patents and international academic publications, the Chinese government defined that in 15 years, China's R&D expenditure in GDP will reach 2.5 percent; science and technology progress will contribute at least 60 percent of the country's development; and the country's reliance on foreign technology will decline to 30 percent and below (Zhu, 2006). Shortly afterwards, this guidelines evolved into a new alternative-technology enhancing strategy: namely, the Independent Innovation Strategy (IIS),

announced S&T Guidelines and IIS both shed more light on improving what is called the "independent innovation capability" of DEs, where SOEs in high-tech industries have been expected to play a leading role, since they account for the bulk of advanced industrial production in China and occupy the country's best R&D resources (Zheng and Chen, 2006). However, the prospect of these ambitious plans being realized is partly dependent on the evaluation of the SOEs' catch-up performance in high-tech industries.

3 Key Factors in Productivity Analysis in China

3.1 Prefatory Remarks

A more straightforward and well-received approach to measure the technology catch-up performance is productivity analysis (Jorgenson, 1995; OECD, 2001; Solow, 1957), particularly when the contribution from technology progress and its determinants, e.g. R&D investment, are under examination (Griliches, 1979, 1986, 1988, 1994). Studies using this approach to investigate China's catch-up performance can be found in the works of Szirmai et al. (2001), Timmer (1999) and Wu (2001). Though far from perfect, productivity analysis does after all rely on composite indicators which can measure a producer's efficiency in utilizing various kinds of resources as input. In contrast, indicators employed by the aforementioned literature, such as the share in total export (Gilboy, 2004), the number of patent obtained (Ning, 2007; Yao, 2006) and R&D intensity (Jefferson, 2005; OECD, 2006), were undoubtedly plagued by their one-dimensional measurement, which merely focused on input or output. Moreover, according to their users, most of these indicators are considered to be an inferior substitute for the productivity indicators. If such is the case, why would these studies relinquish the idea of conducting a productivity analysis?

A standard productivity analysis normally requires the data on input to conform to a stock measurement. Therefore, acute problems such as the data's availability and reliability may stem from the process of capital stock estimation (i.e. tangible fixed assets, as given in the 1993 SNA) and ultimately prevent the researchers from adopting this approach. In the case of China, for instance, since the official data available on fixed assets suffer from inappropriate treatments of aggregation and depreciation, inconsistencies in industrial classification, and lack of information on prices, the estimation of capital stock has become a major obstacle to accurately assess the productivity performance of the Chinese economy as a whole or across different industries (Holz, 2006; Wu and Xu, 2002). This dilemma explains, to some extent, the elusion from the current literature of productivity analysis as an approach to investigate DEs' catch-up performance in China's high-tech industries.

---

which was first referred to in China's "11th Five-Year Plan" announced in October 2006 (Pan,2006) and then reaffirmed by the CPC's "Scientific Outlook on Development" promulgated one year later (Hu,2007).

The pilot studies of Wang and Szirmai (2003b; 2005), however, probed this terra incognita. Their preliminary empirical results, in particular, the estimation of net capital stock and net R&D capital stock across China's high-tech industries, became very helpful benchmarks for the future research. Meanwhile, the theoretical and operational guidelines offered by their works suggested directions for others to follow as well. As long as there are properly structured data sets, the progress they made, as described above, will allow successors to proceed from more disaggregated aspects, especially some comparative productivity analyses among predefined individuals.

3.2 Measuring the Capital Stock by Ownership

In this subsection, we attempt to estimate the capital stock of SOEs and FFEs[5], respectively, across every Chinese high-tech industry from 1996 to 2006. This attempt is made possible mainly by a combination of the intellectual guidance from Wang and Szirmai (2003b; 2005) and the recently publicized data from China's National Bureau of Statistics (NBS, 2002, 2007b), where the aggregate data at industry level have been decomposed by ownership, by firm size, and by province.

However, it is noteworthy that, rather than an unconditional acceptance of Wang and Szirmai's (2003b; 2005) methodology, our estimation of the capital stock by ownership in China's high-tech industries was simply based on the official "net value of fixed assets" (*Guding Zicha Jingzhi*) deflated by the national annual price index for fixed assets investment(NBS, 2007a). Such simplification can be justified by the following two aspects in principle:

First, in order to comply with the Perpetual Inventory Method (PIM), Wang and Szirmai (2003b; 2005) imposed a great many data assumptions in their estimation which are incompatible with the specific requirements of, and availability of data for our research. For instance, Wang and Szirmai applied the incremental capital-output ratios (ICORs) proposed by Timmer (1999) to calculate the initial benchmark estimate of the capital stock, which assumes that the incremental capital-output ratio will approximate the average capital-output ratio if the economy is at full capacity. However, we can not really we believe that the newly sprung high-tech industries in China, operating in an environment of constant policy and technology change, have been working at full capacity during the reform period, especially considering their abrupt increase in production capacity after China's accession to the World Trade Organization (WTO) in 2001. At this point, even the averaged ICORs which Wang and Szirmai eventually adopted in their research would not prevail in the Chinese economic context. Therefore, while, according to PIM, the time series of investment available from NBS(2002; 2007b) are too short to construct an initial benchmark estimate separately for SOEs and FFEs in each high-tech industry, Wang and Szirmai's solution with the unrealistic assumption mentioned above appears to be undesirable as well.

[5] In the *China Statistic Book on High Technology Industry* (NBS, 2002, 2007b), an alternative expression of "FFEs" has been adopted: namely, the "Tri-capitalized Enterprises" (*Sanzi Qiye*), which includes the subcategories: the "Sino-foreign Joint Ventures", the "Sino-foreign Cooperative Enterprises" and the "Wholly Foreign-owned Enterprises".

This is because further assumptions have to be made to decompose ICORs by ownership, which all together will intensify the deviation from reality to an unacceptable extent. Likewise, the breakdown of fixed assets by major asset type and the differentiation of depreciation rates by industry can not be performed either.

Second, as a matter of fact, the official aggregate industrial data in China generally can not be applied for PIM without overall revaluations (OECD, 2003). But serious revaluations so far have usually relied on unpublished sources and, ironically, some arbitrary assumptions (Wu and Xu, 2002). In this regard, caution should be exercised when such revaluations are employed, since sometimes the cure might be worse than the disease. The worry about choosing a "bad cure" hence obliges us to search for a new proxy for capital stock instead of the PIM estimation—the Chinese convention of calculating the current year's gross capital stock or "original value of fixed assets" in official terms is to add the value of the investment in fixed assets in the current year to the value of the existing stock of fixed assets at historical or acquisition prices; the official net capital stock or "net value of fixed assets", also at historical prices, is evidently obtained by applying some unpublicized depreciation rates to this stock. This convention is accused of failing to deflate the capital stock which is mixed with different types of assets, e.g. buildings, equipment and machinery, and of making no attempt to clarify the depreciation method (Wang and Szirmai, 2005; Wu and Xu, 2002). However, if we tolerate the unexplained depreciation rates underlying the official net capital stock and apply a common yet weighted fixed assets deflator (NBS, 2007a) to it, the methodological and operational consistency will be retained in the new data set (OECD, 2003). We would certainly not claim the superiority of our methodology over the PIM estimation before better data sets and more comparable empirics become available. But for the purpose of this paper, at least, our simplification will suffice without risking the "bad cure".

Applying the methodology above, we obtain the net capital stock for SOEs and FFEs across the high-tech industries (Appendix Table B-1).

3.3 R&D Capital Stock and Other Inputs

Also indispensable in this research is the estimation of R&D capital stock which accordingly serves the efficiency analysis of R&D input, the key independent variable for the development of endogenous technology capability, is. By following the methodology proposed in Wang and Szirmai (2003b), we could obtain the R&D capital stock of SOEs and FFEs in China's high-tech industries from 1996 to 2006 (Appendix Table B-2). Since our estimation strictly obeyed the technical guidance established by Wang and Szirmai, for the sake of brevity, we will not repeat those principles here. One slight adjustment, however, is that we manage to find that the average real wage index (NBS, 2007a) is a more accurate substitute for the consumer price index employed by Wang and Szirmai, in the calculation of the R&D price index.

The drawbacks of Wang and Szirmai's methodology are again those strong assumptions (to name just a few) that are imposed on the structure of the lag operator which connects past R&D expenditure to the current increase in technological knowledge, i.e. the rate of obsolescence of R&D capital; and the isolation from knowledge spillovers. As a matter of fact, this defect of arbitrary assumption is still a universal hurdle to a more reliable estimation of R&D capital stock, especially because of the data constraints (Griliches, 1979, 1994).

In our data set, fortunately, there is a non-monetary R&D input measurement in a flow sense: namely, the man-years statistic in R&D activities which is exempted from the preceding assumptions. The man-years (or man-hours) statistic in general production activities has been widely accepted and applied as a proxy for labour input in developed countries (Lucas, 1990; Mankiw et al., 1992; Solow, 1957). Accordingly, it is reasonable to infer a definition of "R&D labour productivity" from the precedent that labour productivity is a measurement for the efficiency of R&D personnel input. Therefore, we expect that the man-years statistic in R&D activities may allow us to compare the R&D input and thus its efficiency between SOEs and FFEs from a complementary perspective.

As usual, man-years (or man-hours) data for general production activities in high-tech industries are not reported by NBS. In response, we follow the convention of Chow and Li (2002), Szirmai et al. (2001) and Wu (2001) to measure the labour input with employment data as a preparation for the calculation of labour productivity.

3.4 The Measurement of Productivity

As is well known, there are different measurements for productivity, and each one is suited to its own purpose. The choice between them depends on the purpose of the productivity measurement and, in many cases, on the availability of data (OECD, 2001). In this paper, we attempt to assess the overall catch-up performance of SOEs (used as a proxy for DEs because of their dominant output share in high-tech industries) compared to FFEs in three dimensions: welfare, efficiency, and technology. Accordingly, we need to first choose the proper productivity measures for each dimension, and then calculate the gap between SOEs and FFEs by comparing the associated productivity measures.

Previous studies which related China's catch-up performance to its productivity change tended to misinterpret some single-factor productivity measures[6], e.g. the labour productivity, as direct indicators for technical change (Szirmai et al., 2001; Wu, 2001). However, labour productivity and capital productivity based on value added are actually only partial productivity measures that reflect the joint influences of a host of factors. A more straightforward and reliable interpretation of labour productivity based on value added should be confined to its link to income per capita, which gives it a welfare significance. Likewise, changes in capital productivity based on value added indicate the extent to which output can be achieved with lower costs in the form of foregone consumption: namely, the efficiency of capital utilization. With respect to technology, conceptually, the capital-labour-energy-materials (KLEMS) multifactor

[6] Single-factor productivity measures are normally calculated by relating a measure of output to a single measure of input, while the multifactor productivity measures are calculated by relating a measure of output to a bundle of inputs (OECD, 2001).

productivity is the most appropriate tool to measure disembodied technical change by industry, as the role of intermediate inputs in production is fully acknowledged. More often than not, as in our case, data and resource constraints do not permit a full coverage of intermediate inputs and the differentiation of labour and capital according to their quality improvement, which blurs the linkage between multifactor productivity and technical change (OECD, 2001).

A review of the notions of the different productivity measures described above enables us to justify that the single labour productivity measure and the capital productivity measure based on value added should be applied to assess the catch-up performance in terms of welfare and efficiency. Meanwhile, it also casts doubt on the reliability of using any productivity measure to properly measure the technology catch-up performance in the light of the data constraints in our research. As a consequence, we have to seek other alternatives to address this issue more explicitly later.

In terms of the productivity of R&D input, conventional output indicators, such as the value of gross output and value added, contain a limited direct contribution from R&D input, particularly in non-high-tech industries. Therefore, single R&D capital productivity and R&D labour productivity seldom appear in previous empirical studies which are grounded in the observations of the manufacturing industries as a whole (Goto and Suzuki, 1989; Griliches, 1979; Hall and Mairesse, 1995; Scherer, 1984). Seen in this light, a new output indicator that strictly relates to R&D input must be considered. In addition, such R&D input productivity measures must be positioned and interpreted very cautiously, since the disregard of cross-industry spillover, which is unavoidably caused by calculating productivity measures independently within a certain industry, tends to underestimate the real productivity of R&D input for those industries whose technology progress can exert great externalities. In response, more researchers have turned to analyze the relationship between R&D input and output growth so as to bypass the tricky spillover problem (Wang and Szirmai, 2003a). In this paper, we will adopt both approaches, aiming to generalize a sound conclusion by comparing their individual results.

4 Results and Discussion

Following the estimation steps explained in Section 3, we can estimate the productivity level of SOEs and FFEs in China's high-tech industries on a comparable basis, because this approach measures the inputs and outputs of SOEs and FFEs using constant values at 1996 prices (Table 2-Table 5). Further, the productivity gap between SOEs and FFEs can be inferred by calculating SOEs' comparative productivity performance (Wu, 2001) as the ratio of the productivity of SOEs to that of the FFEs in the same industry. Readers should concentrate on two concepts in the discussion below: first, the "productivity gap", which will be "increased" (reduced) when the SOEs' comparative productivity performance "declines" (climbs); second, the "comparative productivity performance", where a decline is in *relative* rather than *absolute* terms[7]. These two concepts will first assist us to reveal the SOEs' catch-up trajectory in different terms of productivity in Section 4.1, and then allow us to analyze the role that competition has played in SOEs' catch-up process in Section 4.2. Finally, section 4.3 will particularly shed light on SOEs' technology catch-up performance on account of the development of their indigenous technology capabilities.

[Insert Table 2- Table 5 here]

4.1 Productivity Gap: the Inverted U-shape Curve

As depicted in Figure 1, for the high-tech industries as a whole, the SOEs' comparative productivity performance in welfare and efficiency terms rose from 0.26 to 0.72 and from 0.45 to 0.54 (FFE=1), respectively. The results indicate a significant catch-up of domestic enterprises measured by labour productivity, but a rather limited one measured by capital productivity. However, a further look at Figure 1 reveals a mixed story: since 1997, both the SOEs' welfare performance and their efficiency performance compared with those of the FFEs' have experienced a steady catch-up, which peaked separately at 0.82 in 2004 and 1.32 in 2003; in contrast, an obvious falling-behind followed afterwards where the comparative welfare performance dropped 10 percent and the comparative efficiency performance dropped 72 percent in 2006. A polynomial fit of the geometric mean (the Fisher average) of the comparative welfare and efficiency performances after 1997 clearly generalizes this mixed story as an inverted U-shape curve (Figure 2).

[Insert Figure 1 and Figure 2 here]

Meanwhile, the trajectories of the comparative productivity performance of the R&D inputs: namely, R&D capital and R&D labour[8], can also to some extent conform to the aforementioned inverted U-shape curve, but with two noteworthy differences: first, instead of a constant increase after 1997, the comparative productivity performances of R&D capital and labour continually stagnated until 2002; second, in spite of the brief catch-up after 2002 and the slight falling-behind thereafter, comparative productivity performances of R&D capital and labour both stay at rather low levels compared with those of conventional capital and labour. These contrasts actually reveal the unfortunate fact that, in terms of their capability to exploit R&D investment to generate innovation, the SOEs in China's high-tech industries have only achieved a minor catch-up during the past decade and are far more disadvantaged compared with their positions measured by conventional inputs such as capital and labour. At this point, our research appears to

---

[7] Therefore, the comparative productivity performance of SOEs declines in the sense that it does not grow not as fast as that of the FFEs, or it declines more rapidly than that of the FFEs. The same applies to an increase in SOEs' comparative productivity performance.

[8] In response to the measurement issue we discussed at the end the of Section 3.4, the value added of the new products with a one-year lag has been chosen to calculate the productivity of R&D capital and R&D labour, taking account of their more direct causal relationship and the delayed effects of R&D inputs on outputs.

echo the suspicions concerning China's indigenous technology capability in high-tech industries (Chen and Shi, 2005; Gilboy, 2004; OECD, 2002; Zhou and Sun, 2006).

Furthermore, the optimism about the SOEs' catch-up becomes more questionable on account of the common falling-behind identified after 2003, which has led people to investigate the causes of the previous catch-up. As has been pointed out in the relevant literature (Mattlin, 2007; OECD, 2002; Pearson, 2007; Zheng and Chen, 2007), the SOEs in China underwent a radical reform from the mid-1990s to the early 2000s, which comprised three major components: economic revitalization; enterprise restructuring; and corporate governance reforms. For instance, a substantial number of redundant workers in SOEs have been taken off enterprise payrolls; the debt levels have been significantly reduced for larger SOEs through debt-equity swaps; and the stock sales of SOEs listed on Chinese and overseas stock markets have further allowed them to finance various liabilities. Such reform measures can, without doubt, can significantly and immediately improve SOEs' comparative productivity performance, especially when it is measured by capital and labour as the input item. On the other hand, simultaneously with the Chinese government's commitment to the diversification of large SOEs so as to include some private ownership of shares, the dominant ownership and control of these firms are to remain firmly in the hands of the state in order to carry out the imperative of the party-state. Meanwhile, the state also mandates the market structure characterized by the SOEs' monopoly or oligopoly in selected lifeline industries, where some high-tech industries such as the Manufacture of Aircraft and Spacecraft, the Electronic and Telecommunications Equipment, and the Manufacture of Medical Equipment and Meters are fully or partially included (Mattlin, 2007; Pearson, 2007). As a result, non-state investors are merely permitted to contribute funds to SOEs without sharing in control, which leaves those inherent problems of SOEs unresolved, such as the soft budget constraints. And, furthermore, SOEs' managers are continually encouraged to rely on imported technologies to maximize their monopoly profits as a shortcut, rather than seriously endeavour to improve efficiency and develop indigenous technology capability for the long run. Therefore, the momentum of catch-up initiated by such superficial reforms is hard to maintain and would soon fade away. The inverted U-shape curve derived from the SOEs' catch-up experience in China's high-tech industries happens to justify this conclusion.

4.2 Catch-up and Competition

It was discussed in the previous section that the state monopoly in selected industries, or in other words, the dispersion of competition, should be accused as one of the main causes for the SOE's inability to sustain their catch-up momentum. In this subsection, we attempt to briefly address this issue with further empirics from China's high-tech industries in view of its importance in relation to the future direction of the reform.

As is known, China's high-tech industries are composed of some industries that are principally state monopolized, e.g. the Manufacture of Aircraft and Spacecraft, some industries that are highly competitive, e.g. the Manufacture of Computers and Office

Equipment, and some industries where state monopoly and competition coexist yet are strictly segregated within regulated sub-industries, e.g. the Manufacture of Medical Equipment and Meters (Jin and Zedtwitz, 2008; Mattlin, 2007). Such a mixed composition has made the high-tech industries a favourable scenario to investigate the influence of competition on SOEs' catch-up performance independently, while the effects of other determinants of SOEs' productivity performance, e.g. the industrial characteristics, are also properly considered during the calculation of the within-industry comparative productivity.

As shown in the study of Ning (2007), the information and communication technology (ICT) manufacturing sector is now the most open and competitive high-tech sector in China, and mainly comprises the Manufacture of Computers and Office Equipment industry and those competitive sub-industries of the Electronic and Telecommunications Equipment industry. Figure 3 presents the SOEs' comparative productivity performances in the ICT sector[9], with their performance in the high-tech industries as a whole as a benchmark.

[Insert Figure 3 here]

Apparently, the SOEs in the ICT sector have a better comparative capital productivity performance than that of their peers in the high-tech industries as a whole: namely, the efficiency gap between SOEs and FFEs in the ICT sector is smaller than that in the high-tech industries as a whole all through the period from 1996 to 2006. A critic may argue here that historically the SOEs in the ICT sector could be more productive, and thus their superiority shown after 1996 should not be attributed to this sector's relatively more competitive market structure. However, in addition to the quicker pace of catch-up in the comparative capital productivity[10], SOEs in the ICT sector, in terms of their comparative productivity performance from the other three perspectives (see Figure 3), evidently started from an inferior position and later managed to catch up and exceed. While such dynamics indisputably support the conclusion that the competition in China's high-tech industries tends to relatively accelerate the DEs' catch-up, on the other hand, they also question the rationality of using state monopoly to improve the competitiveness of SOEs.

4.3 R&D and the Indigenous Technology Capability

We have as yet not been able to address the issue of the SOEs' technology catch-up. In line with our discussion at the end of Section 3.4, the serious data constraint in this research has meant that the most appropriate productivity measurement of technology progress, viz. multifactor productivity, is unavailable. The total factor productivity (TFP) measurement, if taken as an alternative, is not reliable either, since our data do

---

[9] The comparative productivity of the ICT sector is measured by the geometric mean (the Fisher average) of the two sub-industries' comparative productivities.

[10] The SOEs' average annual growth rate of comparative capital productivity in the ICT sector (14 percent) is 5 percent higher than that in the total high-tech industries (9 percent).

not take account of the quality improvement of different inputs and will inevitably mix TFP with embodied technical progress (OECD, 2001; Triplett, 1989). However, with reference to the argument about China's technology catch-up performance in the high-tech industries (Section 2), we found that the divergence in fact sources back to the judgment of whether the DEs have successfully developed their indigenous technology capabilities with their regular R&D inputs (Fan, 2006; Gilboy, 2004; Jefferson, 2005; Ning, 2007). Therefore, in an attempt to address this concern, another common and popular approach is being employed to examine the relationship between R&D and productivity: namely, taking R&D inputs as another type of capital which is to be added to the list of input variables in an aggregate production function (Goto and Suzuki, 1989; Griliches, 1994; Hall and Mairesse, 1995; Wang and Szirmai, 2005).

The Model

First, we define an aggregate production function in Cobb-Douglas style:

$$Y=Ae^{\lambda t}K^{\alpha}L^{\beta}R^{\gamma} \tag{1}$$

where Y is output; K and L represent, respectively the physical capital input and the labour input, R is the R&D input; A is a constant; λ is the rate of disembodied "external" technical change (t is the time trend); α is the output elasticity for the capital input; β is the output elasticity for the labour input; and γ is the output elasticity for the R&D input. Equation (1) can be simply transferred into logarithmic terms as :

$$\text{Log } Y=\text{Log } A+\lambda t+\alpha \text{Log } K+\beta \text{Log } L+\gamma \text{Log } R \tag{2}$$

for a straightforward estimation. In particular, if γ is estimated to be significant and positive, it can be concluded that the endogenous R&D activity has been integrated into the production process as an indispensable input, which signifies the development of an indigenous technology capability to create or adopt new technology and improve the volume of output (Furman and Hayes, 2004; Nelson and Pack, 1999). Empirically, Equation (2) has been estimated by Griliches (1980; 1986), and by Hall and Mairesse (1995) using longitudinal firm-level data, and by Griliches (1973) and Wang and Szirmai (2003a) using industry-level data. The estimated elasticity of output with respect to R&D input lies between 0.05 and 0.2, with the only estimate based on the Chinese data from high-tech industries being 0.11.

Estimation Results

The basic descriptive statistics that could be applied in the estimation of Equation (2) are described in Table 6 while the correlation matrix of the variables is displayed in Table 7. Apparently, an estimation that attempts to include all the independent variables listed in Equation (2) will result in a serious multicollinearity problem because of their fairly high correlation coefficients (Table 7). In response, we propose to respecify Equation (2) by combining and eliminating selected independent variables in order to mitigate multicollinearity.

[Insert Table 6- Table 7 here]

With respect to the conventional inputs, the variable representing physical capital stock is more related to the output proxy, which means that it is more suitable than the labour variable to be retained in the model. The R&D capital stock variable also has a higher correlation coefficient on the output variable compared with that of the R&D labour variable. However, since the capital stock variable has already incorporated a great deal of the information from the R&D capital variable (a correlation coefficient of 0.8423) while the R&D labour variable captures more information of the dropped labour variable (a correlation coefficient of 0.7789), we are inclined to keep the R&D labour variable, which is denoted by "R-Labour" in Equation (3), to represent the contributions from both R&D inputs and labour (Baum, 2006; Liu and Buck, 2007). As a result, Equation (2) is finally reduced to Equation (3) for the estimation:

$$\text{Log } Y = \text{Log } A + \lambda t + \alpha \text{Log } K + \gamma \text{Log (R-Labour)} \quad (3)$$

In Table 8, we report the estimation results for the SOEs in China's high-tech industries. According to the outcome of the model specification test (Hausman test), the "fixed effect (within)" model has been chosen to estimate each independent variable's coefficient: the output elasticity of capital is not significant; the output elasticity of R&D labour has a significant yet abnormal negative value; a very low R-square value at 0.40 additionally indicates a poor goodness of fit. Further diagnostic statistics, i.e. the Wald test result and the Wooldridge test result, suggest that the estimation has been plagued by the heteroskedasticity across different industries and by the autocorrelation in panel data. In response, we switch to the estimation of the "robust fixed-effect model" by calculating the panel-corrected standard error (PCSE) estimates, which can properly address problems such as groupwise heteroskedasticity, within panel autocorrelation, and contemporaneous correlation across panels (Baum, 2006).

In the robust fixed-effect model, estimations based on the SOEs' data, again deny the significant contribution from the R&D labour. Further, in spite of a significant and justifiable coefficient of the capital variable, the poor goodness of fit (0.39) still casts doubt on the underlying assumption of Equation (1)-(3) that R&D activities have been integrated into SOEs' production process to generate indigenous technology capability. In contrast, estimations using the FFEs' data yield significant and interpretable results for each variable and a much more acceptable goodness of fit (0.69). This sharp contrast, in combination with the analysis presented in Section 4.1, reveals that China's DEs in high-tech industries have made very limited progress in the past decade in catching up with FFEs in terms of the development of indigenous technology capability.

[Insert Table 8 here]

Sensitivity Analysis

In Wang and Szirmai's (2003a) study, the overall capital stock of each high-tech industry was estimated by PIM without differentiating according to ownership.

Meanwhile, they adopted R&D capital stock instead of R&D labour to estimate the contribution of R&D input to output growth (Equation (2)) measured by the value added. Their estimation of the output elasticity of R&D input (γ) is 0.1069. Liu and Buck (2007) estimated Equation (2) with the same new products' value added as the output measurement that we used, and the R&D intensity (the ration of R&D expenditure to total sales) as the R&D input. Their results revealed a γ of 0.086 for the high-tech industries as a whole. Our estimation result of γ for FFEs is reasonably slight higher, because it has explicitly excluded the lower γ of the SOEs in comparison with the "mixed" results of the two foregoing studies. This comparison also proves that our estimation of γ is robust to the measurement selection of capital stock, output, and R&D input.

5 Concluding Remarks

This study contributes to the debate on whether China's DEs have experienced a significant catch-up compared with FFEs in the high-tech industries. It has estimated a new set of capital stock and R&D capital stock by ownership for China's high-tech industries. Then, based on the newly constructed data set, we have assessed SOEs' (as the most important proxy for DEs) comparative productivity performance in the high-tech industries from 1996 to 2006.

First, our findings identify an inverted U-shape curve to generalize SOEs' productivity catch-up performance. The common relative falling-behind after 2003 and the rather low productivities of R&D input together stress the necessity to sustain the SOEs' catch-up with deeper structural and institutional reforms rather than rely on short-term policy subsidies.

Secondly, since a better catch-up performance has been found in those industries (i.e. the ICT sector) that are more open and competitive, our findings strongly oppose excessive state monopoly in the high-tech industries, which in the long run removes the pressure for SOEs to maintain their catch-up efforts.

Lastly, our findings reveal that the SOEs in China's high-tech industries have so far failed to develop their own indigenous technology capability, which is embodied by the integration of R&D in the production process as an indispensable input. In comparison with their clear catch-up in terms of welfare and efficiency, SOEs' technology catch-up measured by indigenous technology capability is still stumbling.

References

Baum, C. (2006). *An Introduction to Modern Econometrics Using Stata*. College Station, Texas: Stata Press.

Chen, J., and Shi, H. (2005). *High-tech Industries In China*. Cheltenham, UK: Edward Elgar Publishing.

Chow, G., and Li, K. W. (2002). China's Economic Growth: 1952-2010. *Economic Development and Cultural Change, 51*(1), 247-256.

Deng, Z., and Treiman, D. (1997). The Impact of the Cultural Revolution on Trends in Educational Attainment in the People's Republic of China. *American Journal of Sociology, 103*(2), 391-428.

Fan, P. (2006). Catching up through developing innovation capability: evidence from China's telecom-equipment industry. *Technovation, 26*(3), 359-368.

Furman, J., and Hayes, R. (2004). Catching up or standing still? National innovative productivity among 'follower' countries, 1978-1999. *Research Policy, 33(*9), 1329-1354.

Gilboy, G. (2004). The Myth behind China's Miracle. *Foreign Affairs, 83(*4), 33-48.

Goto, A., and Suzuki, K. (1989). R&D Capital, Rate of Return on R&D Investment and Spillover of R&D in Japanese Manufacturing Industries. *The Review of Economics and Statistics, 71(*4), 555-564.

Griliches, Z. (1973). Research Expenditure and Growth Accounting. In B. R. Williams (Ed.), *Science and Technology in Economic Growth.* London: MacMillan. 59-95.

Griliches, Z. (1979). Issues in Assessing the Contribution of Research and Development to Productivity Growth. *The Bell Journal of Economics, 10* (1), 92-116.

Griliches, Z. (1980). Returns to Research and Development Expenditure in the Private Sector. In J. W. Kendrick and B. Vaccara (Eds.), *New Developments in Productivity Measurement* (Vol. 44). Chicago: Chicago University Press. 419-454.

Griliches, Z. (1986). Productivity, R&D and Basic Research at the Firm Level in the 1970s. *American Economic Review, 76(*1), 141-154.

Griliches, Z. (1988). Productivity Puzzles and R & D: Another Nonexplanation. *The Journal of Economic Perspectives, 2(* 4), 9-21.

Griliches, Z. (1994). Productivity, R&D, and the Data Constraint. *American Economic Review, 84(*1), 1-23.

Hall, H., and Mairesse, J. (1995). Exploring the Relationship between R&D and Productivity in French Manufacturing Firms. *Journal of Economics, 65,* 263-293.

Holz, C. (2006). New capital estimates for China. *China Economic Review, 17(*2), 142-185.

Hu, J. (2007). *Full text of Hu Jintao's report at 17th Party Congress.* Retrieved March

26, 2008, from http://news.xinhuanet.com/english/2007-10/24/content_6938749_2.htm

Jefferson, G. (2005). R&D and Innovation in China: Has China Begun Its S&T Takeoff? *Harvard China Review, 5(*2), 44-50.

Jin, J., and Zedtwitz, M. (2008). Technological Capability Development in China's Mobile Phone Industry. *Technovation, 28(*3), 327-334.

Jorgenson, D. W. (1995). *Productivity.* Cambridge, Mass.: MIT Press.

Liu, X., and Buck, T. (2007). Innovation performance and channels for international technology spillovers: Evidence from Chinese high-tech industries. *Research Policy, 36(*3), 355-366.

Lucas, R. (1990). Why Doesn't Capital Flow from Rich to Poor Countries? *American Economic Review, 80(*2), 92-96.

Mankiw, N., Romer, D., and Weil, D. (1992). A Contribution to the Empirics of Economic Growth. *Quarterly Journal of Economics, 107(*2), 407-437.

Mattlin, M. (2007). *The Chinese Government's New Approach to Ownership and Financial Control of Strategic State-Owned Enterprises.* Paper presented at the SSRN eLibrary.

NBS. (2002). C*hina Statistic Yearbook on High Technology Industry.* Beijing: China Statistics Press.

NBS. (2007a). C*hina Statistic Yearbook on Finance.* Beijing: China Statistics Press.

NBS. (2007b). C*hina Statistic Yearbook on High Technology Industry.* Beijing: China Statistics Press.

Nelson, R., and Pack, H. (1999). The Asian Miracle and Modern Growth Theory. *The Economic Journal, 109(*457), 416-436.

Ning, L. (2007). Economic Liberalization for High-tech Industry Development? Lessons from China's Response in Developing the ICT Manufacturing Sector Compared with the Strategies of Korea and Taiwan. *Journal of Development Studies, 43(*3), 562-587.

OECD. (2001). *Measuring Productivity: OECD Manual: Measurement of Aggregate and Industrial-Level Productivity Growth.* Paris: OECD.

OECD. (2002). *China in the world economy the domestic policy challenges.* Paris: OECD.

OECD. (2003). *Preliminary Measurement of State-Owned Fixed Capital Stock in China.* Retrieved May 26, 2008, from http://www.oecd.org/dataoecd/21/4/31642072.pdf

OECD. (2004). *Chinese Standard of Industrial Classification and its Relationship to ISIC.* Retrieved May 26, 2008, from http://www.oecd.org/dataoecd/32/24/33982319.pdf

OECD. (2006). *OECD Science, technology and industry outlook 2006.* Paris: OECD.

OECD. (2007). *Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs.* Paris: OECD.

Pan, L. (2006). *Key points of the 11th Five-Year Plan.* Retrieved March 26, 2008, from http://english.gov.cn/2006-03/07/content_246929.htm

Pearson, M. M. (2007). Governing the Chinese Economy: Regulatory Reform in the Service of the State. *Public Administration Review, 67(*4), 718-730.

Scherer, F. (1984). Using Linked Patents and R&D Data to Measure Interindustry

Technology Flows. In Z. Griliches (Ed.), R*&D, Patents, and Productivity.* Chicago: Chicago University Press. 417-464.

Simon, D. F. (1989). China's Drive to Close the Technological Gap: S&T Reform and the Imperative to Catch Up. *The China Quarterly(*119), 598-630.

Solow, R. (1957). Technical Change and the Aggregate Production Function. *Review of Economics and Statistics, 39,* 312-320.

Story, J. (2005). China: Workshop of the world? *Journal of Chinese Economic and Business Studies, 3(*2), 95-109.

Szirmai, A., Bai, M., and Ren, R. (2001). Labour Productivity Trends in Chinese Manufacturing, 1980-1999. *Ecis Working Paper.*

Timmer, M. (1999). *The Dynamics of Asian Manufacturing: A Comparative Perspective, 1963-1993.* Eindhoven University of Technology, Eindhoven.

Triplett, J. E. (1989). Price and Technological Change in a Capital Good: A Survey of Research on Computers. In D. W. Jorgenson (Ed.), *Technology and Capital Formation.* Cambridge, MA: MIT Press. 127-213.

Wang, L., and Szirmai, A. (2003a). Technological Inputs and Productivity Growth in China's High-Tech Industries. *Ecis Working Paper.*

Wang, L., and Szirmai, A. (2003b). Technological Inputs and Productivity Growth in China's High-Tech Industries. Ec*is Working Paper.*

Wang, L., and Szirmai, A. (2005). Comparative Analysis of Capital Productivity in China's High-tech Industries. *China & World Economy, 13 (2*), 93-105.

Wu, H. X. (2001). China's Comparative Labour Productivity Performance in Manufacturing, 1952-1997, Catching up or Falling behind? *China Economic Review, 12,* 162-189.

Wu, H. X., and Xu, X. (2002). *Measuring the Capital of Stock in Chinese Industry.* Paper presented at the 27th General Conference of International Association for Research in Income and Wealth, Stockholm, Sweden.

Yao, S. (2006). Building a Strong Nation: How Does China Perform in Science and Technology? *China Policy Institute's Briefing Series (1*5).

Zheng, Y., and Chen, M. (2006). China Plans to Build an Innovative State. *China Policy Institute's Briefing Series (9*).

Zheng, Y., and Chen, M. (2007). China's Recent State-owned Enterprise Reform and Its Social Consequences. *China Policy Institute's Briefing Series(2*3).

Zhou, Y., and Sun, Y. (2006). Introduction :Mediating State and Market in China's Competitive High Technology Industry. *The China Review, 6(1*), 1-7.

Zhu, L. (2006). *China issues S&T development guidelines.* Retrieved March 26, 2008, from http://www.gov.cn/english/2006-02/09/content_183426.htm

Figure 1 Comparative productivity performances of SOEs in China's High-tech Industries, 1996-2006 (FFEs= 1)

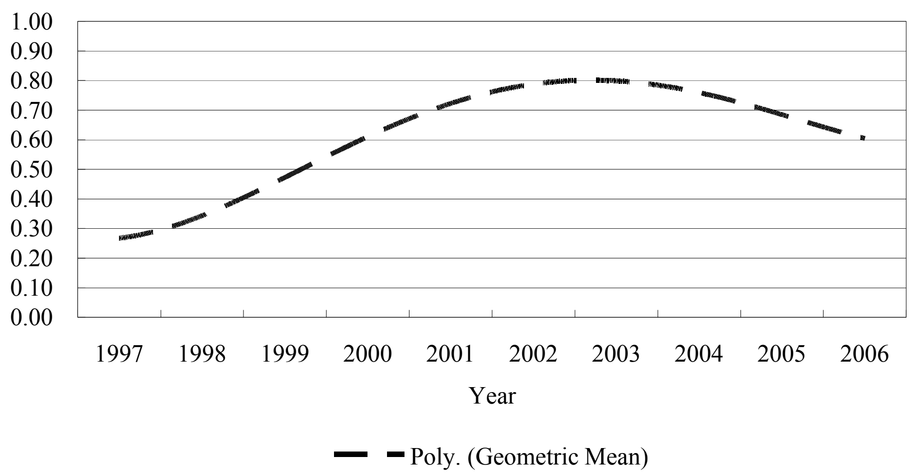

Figure 2 The geometric mean of comparative capital and labour productivity performances of SOEs in China's high-tech industries (polynomial fit), 1997-2006 (FFEs=1)

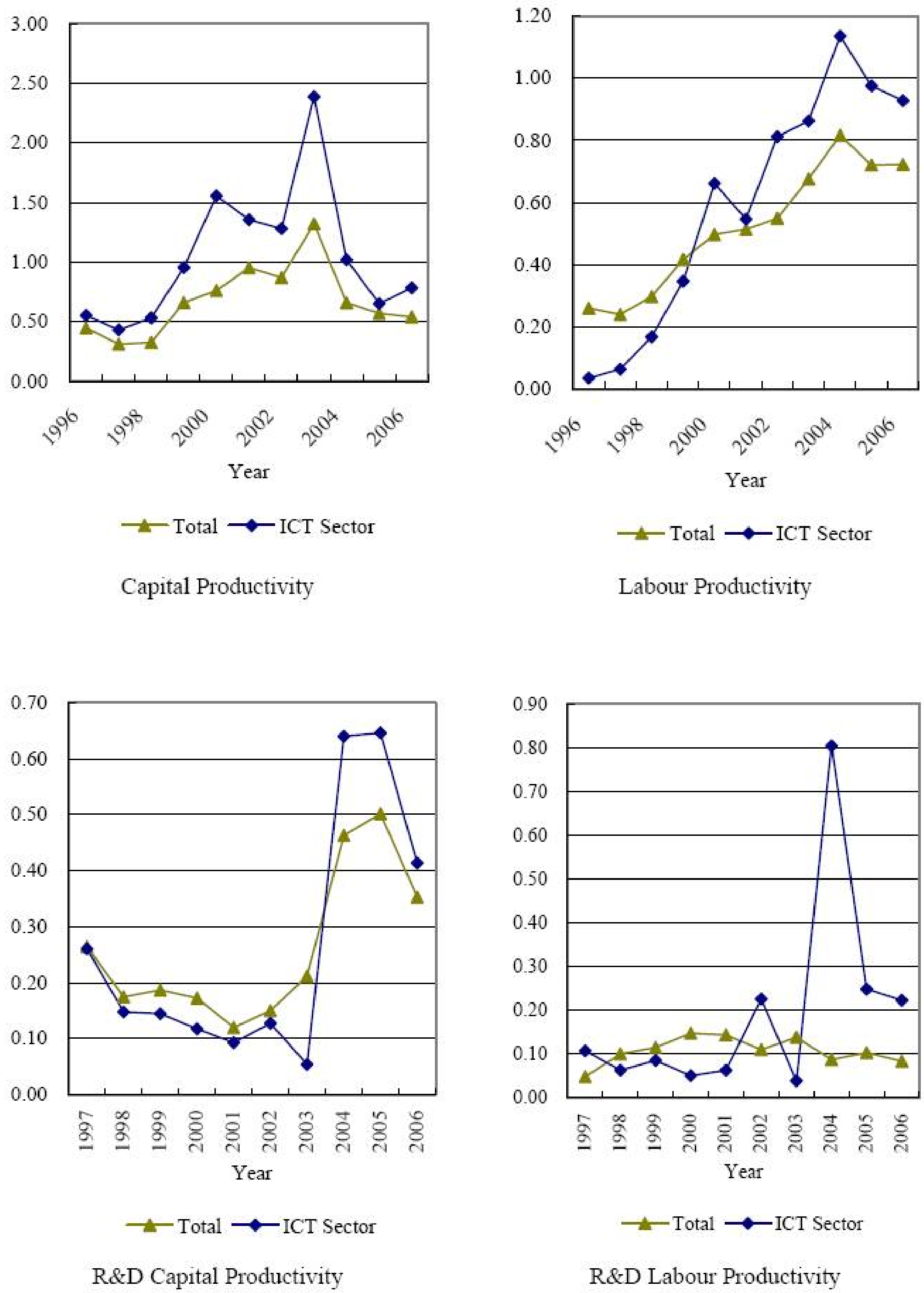

Figure 3 Comparative productivity performance of SOEs in China's ICT sector, 1996-2006 (FFEs= 1)

Table 1 The Codes for High-tech Industries in China's "Industrial Classification for National Economic Activities" (ICNEA)

	ICNEA GB/T4754-2002	ISIC Revision 3
Manufacture of Medical and Pharmaceutical Products	**27**	**2423**
1.Chemical Pharmaceutical Products	2710&2720	
2. Processing of Traditional Chinese Medicine	2730&2740	
3. Biology Products	2750	
Manufacture of Aircraft and Spacecraft	**376**	**353**
1. Manufacture and Repair of Aircraft	3761	
2. Manufacture of Spacecraft	3762	
Electronic and Telecommunications Equipment	**40**	**32**
1. Telecommunication Equipment	401	
Telecommunication Transmission Unit	4011	
Telecommunication Exchange Unit	4012	
Telecommunication Terminal Unit	4013	
2. Radar and Peripheral Equipment	4020	
3. Broadcast and Television Equipment	403	
4.Electronic Apparatus	405	
Electronic Vacuum Apparatus	4051	
Semiconductor Separated Parts	4052	
Integrated Circuits	4053	
5.Electronic Components	406	
6. Household Audiovisual Equipment	407	
7. Other Electronic Equipment	4090	
Manufacture of Computers and Office Equipment	**404& 415**	**30**
1. Computers	4041	
2.Peripheral Equipment of Computer	4043	
3. Office Equipment	415	
Manufacture of Medical Equipment and Meters	**368&411**	**33**
1.Medical Equipment and Instruments	368	
2.Instruments and Meters	411	

Note: The terminology for each respective industry in accordance to the ISIC code above is: Pharmaceuticals-2423; Aircraft and Spacecraft-353; Radio, TV and Communication Equipment-32; Office and Computing Machinery-30; Medical, Precision and Optical Equipment-33.

Sources: (OECD, 2004, 2006).

Table 2 Summary of Capital Productivity[1] of FFEs and SOEs in China's High-tech Industries, 1996-2006

ICNEA	FFEs			SOEs		
	1996-2001 Mean	2002-2006 Mean	Growth Rate 1996-2006 (%)	1996-2001 Mean	2002-2006 Mean	Growth Rate 1996-2006 (%)
Total	**1.10**	**1.05**	**21.53**	**0.64**	**0.83**	**119.61**
27	**1.17**	**1.36**	**31.23**	**0.70**	**0.83**	**66.51**
2710&2720	0.91	1.17	68.32	0.53	0.61	56.36
2730&2740	2.32	1.68	-18.8	1.84	2.23	117.02
2750	1.61	3.54	-23.19	0.73	1.06	96.54
376	**0.61**	**0.59**	**143.98**	**0.25**	**0.40**	**66.69**
3761	0.67	0.59	143.34	0.25	0.39	54.94
3762	N/A	N/A	N/A	0.24	0.46	185.60
40	**0.95**	**0.83**	**19.17**	**0.91**	**1.05**	**165.98**
401	1.48	1.88	483.57	1.62	2.69	456.10
4011	1.84	1.66	5.48	0.92	1.36	156.50
4012	1.98	1.72	29.41	2.72	3.26	549.61
4013	1.72	1.16	-23.49	0.97	1.47	336.62
4020	N/A	N/A	N/A	0.31	0.66	126.07
403	N/A	2.07	N/A	0.20	1.16	673.64
405	0.41	0.38	-29.65	0.53	0.55	69.72
4051	0.35	0.29	-57.07	0.70	0.48	17.38
4052	2.04	0.39	-79.35	0.38	0.64	190.89
4053	0.47	0.34	-51.02	0.22	0.81	784.92
406	1.21	0.78	-36.68	0.50	0.66	141.61
407	1.33	1.64	32.18	1.37	1.55	129.56
4090	2.21	1.89	26.42	1.81	1.30	189.05
404& 415	**2.28**	**1.93**	**-6.50**	**2.12**	**2.40**	**167.35**
4041	4.28	2.75	169.80	1.94	3.01	373.15
4043	2.63	1.60	-63.86	4.41	2.57	72.67
415	2.51	2.14	-1.31	0.23	1.35	361.83
368&411	**1.39**	**1.94**	**39.96**	**0.41**	**0.72**	**143.78**
368	1.42	2.64	56.80	0.93	1.28	104.06
411	1.39	1.78	41.32	0.36	0.67	160.04

Note: 1. Capital productivity is calculated by dividing the volume of value added with the volume of capital stock.

Table 3 Summary of Labour Productivity [1] of FFEs and SOEs in China's High-tech Industries, 1996-2006

ICNEA	FFEs			SOEs		
	1996-2001 Mean	2002-2006 Mean	Growth Rate 1996-2006 (%)	1996-2001 Mean	2002-2006 Mean	Growth Rate 1996-2006 (%)
Total	**10.16**	**13.71**	**112.35**	**4.01**	**9.51**	**489.50**
27	**11.01**	**16.24**	**118.20**	**3.87**	**8.77**	**411.25**
2710&2720	11.12	19.13	176.97	3.52	7.89	370.94
2730&2740	10.23	12.35	52.81	4.67	10.42	442.95
2750	13.74	22.25	138.17	5.55	11.18	314.55
376	5.88	18.42	-298.46	1.97	5.23	538.25
3761	5.99	18.61	-300.90	2.00	5.12	500.20
3762	N/A	10.41	N/A	1.81	6.74	963.18
40	**9.59**	**12.44**	**126.25**	**5.70**	**12.94**	**452.27**
401	21.99	28.23	260.34	9.35	20.58	385.95
4011	19.03	16.68	20.61	5.89	10.46	337.78
4012	34.47	42.76	111.86	19.35	41.35	209.56
4013	14.16	14.08	80.56	4.99	8.78	330.28
4020	N/A	N/A	-91.17	1.59	6.71	741.73
403	4.48	6.27	182.31	1.04	4.73	1275.85
405	10.34	15.27	81.18	5.12	10.35	241.68
4051	17.98	22.01	4.86	7.09	11.01	74.30
4052	5.02	9.73	248.08	2.02	6.81	671.65
4053	7.49	18.68	274.28	5.00	15.77	1994.66
406	5.11	7.15	136.44	2.42	7.16	900.34
407	9.14	11.51	81.71	8.02	15.94	368.58
4090	6.04	8.18	121.12	5.57	12.74	1196.00
404& 415	**15.40**	**17.39**	**12.77**	**11.17**	**21.59**	**276.94**
4041	21.37	23.66	-4.02	13.18	30.35	709.93
4043	15.07	15.14	3.19	9.93	14.64	26.34
415	10.04	16.01	79.16	2.02	9.15	529.72
368&411	**5.91**	**10.95**	**230.09**	**1.83**	**5.24**	**726.35**
368	6.59	14.02	195.30	2.22	5.39	294.85
411	5.65	10.03	256.32	1.76	5.21	830.98

Note: 1. Labour productivity is calculated by dividing the volume of value added with the volume of industrial employment. The unit here is 10 thousand RMB per worker.

Table 4 Summary of R&D Capital Productivity [1] of FFEs and SOEs in China's High-tech Industries, 1997-2006

ICNEA	FFEs			SOEs		
	1997-2001 Mean	2002-2006 Mean	Growth Rate 1997-2006 (%)	1997-2001 Mean	2002-2006 Mean	Growth Rate 1997-2006 (%)
Total	**24.83**	**20.46**	**5.09**	**4.40**	**6.81**	**40.25**
27	**4.12**	**4.22**	**23.01**	**2.53**	**4.39**	**154.53**
2710&2720	4.56	4.98	28.40	2.83	4.20	128.95
2730&2740	1.96	2.39	82.50	2.46	7.13	147.76
2750	N/A	N/A	N/A	0.57	1.52	438.22
376	**N/A**	**N/A**	**N/A**	**1.26**	**3.14**	**275.41**
3761	N/A	N/A	N/A	1.33	3.63	295.55
3762	N/A	N/A	N/A	0.94	0.39	-34.07
40	**25.21**	**18.72**	**-43.09**	**9.97**	**10.45**	**-32.01**
401	19.57	17.60	64.47	5.89	9.46	-48.12
4011	N/A	N/A	N/A	10.08	4.23	-62.21
4012	6.55	6.24	215.30	4.46	9.40	-91.38
4013	140.17	17.49	-94.02	6.03	10.24	303.88
4020	N/A	N/A	N/A	1.58	4.11	334.79
403	N/A	N/A	N/A	1.00	1.86	320.65
405	17.60	18.07	-37.85	6.79	8.73	-13.52
4051	18.50	12.06	-60.16	12.82	8.02	-67.41
4052	N/A	N/A	N/A	1.33	2.74	134.05
4053	14.80	14.26	150.53	4.56	7.46	4.22
406	48.47	18.45	-86.36	5.10	6.02	169.48
407	41.52	25.53	-72.44	31.94	15.81	-71.79
4090	8.17	2.15	-55.91	6.13	8.37	13.35
404& 415	**98.23**	**36.13**	**-69.80**	**6.72**	**9.82**	**-36.32**
4041	236.28	35.33	552.78	7.09	10.34	-34.43
4043	97.87	38.25	-79.47	7.26	8.33	-61.57
415	N/A	N/A	N/A	1.49	12.67	549.92
368&411	**18.41**	**11.26**	**-64.30**	**4.08**	**4.41**	**6.79**
368	5.34	4.88	0.18	4.56	5.23	64.25
411	43.00	14.84	-84.75	4.05	4.30	-1.68

Note: 1. R&D Capital productivity is calculated by dividing the volume of new products' value added with the volume of R&D capital stock in the previous year.

Table 5 Summary of R&D Labour Productivity [1] of FFEs and SOEs in China's High-tech Industries, 1997-2006

ICNEA	FFEs			SOEs		
	1997-2001 Mean	2002-2006 Mean	Growth Rate 1997-2006 (%)	1997-2001 Mean	2002-2006 Mean	Growth Rate 1997-2006 (%)
Total	**11.91**	**12.91**	**87.15**	**0.79**	**2.43**	**223.19**
27	**3.11**	**3.22**	**-5.55**	**0.75**	**1.77**	**288.13**
2710&2720	4.08	4.14	-31.02	0.90	1.74	246.22
2730&2740	1.37	1.86	58.50	0.50	3.74	261.60
2750	4.51	1.83	82.85	0.15	0.57	892.19
376	**N/A**	**5.05**	**N/A**	**0.22**	**0.87**	**642.82**
3761	N/A	5.05	N/A	0.23	0.95	716.94
3762	N/A	N/A	N/A	0.23	0.16	-9.73
40	**11.86**	**12.05**	**41.32**	**1.93**	**4.93**	**75.64**
401	9.91	15.81	463.35	1.34	7.64	-10.97
4011	N/A	0.62	N/A	1.91	3.50	105.48
4012	3.80	7.39	737.13	1.21	12.35	-93.02
4013	42.91	17.09	-12.25	1.08	5.49	394.36
4020	N/A	N/A	N/A	0.31	1.15	1035.47
403	N/A	N/A	N/A	0.13	0.74	1373.36
405	14.67	12.76	-70.67	0.82	3.76	214.32
4051	25.61	12.34	-86.84	2.59	4.28	81.91
4052	2.06	12.58	215.90	0.19	0.71	231.73
4053	83.08	9.81	82.89	0.66	5.32	782.27
406	12.41	7.42	-75.80	0.80	2.09	853.21
407	20.34	16.78	145.28	9.02	14.72	-43.37
4090	1.38	4.51	2405.34	1.03	2.12	454.86
404& 415	**36.00**	**22.20**	**-37.62**	**1.16**	**5.55**	**114.89**
4041	N/A	28.52	1490.61	1.14	6.98	261.30
4043	46.88	22.39	-62.55	2.26	5.20	-43.53
415	N/A	6.91	N/A	0.32	4.85	601.77
368&411	**3.72**	**3.95**	**45.57**	**0.36**	**0.98**	**279.30**
368	1.94	3.09	91.15	0.72	2.46	564.65
411	4.89	4.08	40.30	0.33	0.89	250.47

Note: 1. R&D Labour productivity is calculated by dividing the volume of new products' value added with the volume of working time. The unit here is 1 million RMB per man-year.

Table 6 Descriptive Statistics of the Variables

Variables		Obs.	Mean	S.D.	Min	Max
Log Y		911	4.17	1.69	-3.84	8.46
(the log of value added)						
Log K		898	4.36	1.55	-0.19	8.55
(the log of capital stock)						
Log L		919	2.10	1.59	-7.01	5.97
(the log of the number in employment)						
Log R	**Log R-Capital**	825	1.98	1.59	-3.56	6.27
	(the log of the R&D capital stock)					
	Log R-Labour	885	2.92	1.65	-2.81	6.89
	(The log of the R&D labour input)					

Table 7 Correlation Matrix of the Variables

	Log Y	Log K	Log L	Log R-Capital	Log R-Labour
Log Y	1.0000				
Log K	0.8513	1.0000			
Log L	0.8226	0.8667	1.0000		
Log R-Capital	0.7997	0.8423	0.7383	1.0000	
Log R-Labour	0.6603	0.7924	0.7789	0.8827	1.0000

Table 8 Estimation Results Based on the SOEs' Data

	Dependent Variable: Log Y		
Independent Variables	**Fixed-Effect Model**	**Robust Fixed-Effect Model**	
	(SOEs)	(SOEs)	(FFEs)
Log A	2.99***	0.79	1.44***
	(0.27)	(0.54)	(0.13)
t	0.11***	0.08	0.05***
	(0.01)	(0.05)	(0.02)
Log K	0.11	0.53***	0.57***
	(0.08)	(0.12)	(0.03)
Log R-Labour	-0.18***	0.04	0.14***
	(0.05)	(0.08)	(0.03)
Diagnostic Statistics			
R-square	0.40	0.39	0.69
Hausman test	97.59***		
Wald test	14292.35***		
Wooldridge test	113.34***		
Num. of obs./ Num. of Groups	308/ 28	308/ 28	269/ 26

Note: The standard error is shown in parentheses; ***Significant at the 0.01 level.

Appendix

A. Basic Data

Table A-1 Price Indexes Used in the Calculation of Capital Stocks and R&D Capital Stocks 1996-2006

	Ex-Factory Price Index of Industrial Products as the Deflator of Value Added	Actual Wage Price Index			Investment in Fixed Assets Price Index
		Average	SOEs	FFEs	
1996	1.000	1.000	1.000	1.000	1.000
1997	0.997	1.011	1.042	1.032	1.017
1998	0.956	1.084	1.112	1.014	1.015
1999	0.933	1.226	1.255	1.126	1.011
2000	0.959	1.366	1.392	1.249	1.022
2001	0.947	1.573	1.618	1.370	1.026
2002	0.926	1.817	1.881	1.506	1.028
2003	0.947	2.035	2.113	1.646	1.051
2004	1.005	2.249	2.347	1.777	1.110

2005	1.054	2.536	2.666	1.962	1.127
2006	1.086	2.859	3.008	2.199	1.144

Source: (NBS, 2007a).

B. Other Data Estimated

Table B-1 Summary of Capital Stocks in China's High-tech Industries by Ownership, 2006

100 million RMB in 1996 price	FFEs		SOEs		Overall	
	Capital Stock	Average Annual Growth Rate[1] (%)	Capital Stock	Average Annual Growth Rate (%)	Capital Stock	Average Annual Growth Rate (%)
Total	5742.75	27.73	2094.02	8.57	8810.95	16.92
Manufacture of Medical and Pharmaceutical Products	351.87	17.37	626.12	10.24	1536.75	20.26
Manufacture of Aircraft and Spacecraft	47.73	47.08	480.51	5.31	529.49	5.59
Electronic and Telecommunications Equipment	4064.25	27.92	788.56	11.90	5164.09	19.42
Manufacture of Computers and Office Equipment	1107.51	38.03	59.54	24.58	1197.54	29.53
Manufacture of Medical Equipment and Meters	171.40	30.59	139.25	4.10	383.09	8.79

Note: 1. The estimation is based on the data from 1996 to 2006.
Source: (NBS, 2002, 2007b).

Table B-2 Summary of R&D Capital Stocks in China's High-tech Industries by Ownership, 2006

100 million RMB in 1996 price	FFEs		SOEs		Overall	
	Capital Stock	Average Annual Growth Rate (%)	Capital Stock	Average Annual Growth Rate (%)	Capital Stock	Average Annual Growth Rate (%)
Total	379.30	38.53	278.84	11.51	856.35	21.34
Manufacture of Medical and Pharmaceutical Products	26.74	15.68	33.23	6.73	100.82	13.52
Manufacture of Aircraft and Spacecraft	N/A	N/A	73.62	4.92	84.66	6.36
Electronic and Telecommunications Equipment	250.97	41.89	138.80	19.53	526.55	30.73
Manufacture of Computers and Office Equipment	90.71	90.65	17.90	21.24	108.74	41.23
Manufacture of Medical Equipment and Meters	9.79	41.51	15.28	13.10	35.82	14.52

Source: Ibid.

List of Acronyms and Abbreviations

CPC	the Communist Party of China
DEs	Domestic Enterprises
FFs	Foreign Firms
FFEs	Foreign-funded Enterprises
GERD	Gross Expenditure on R&D
HMT	Hong Kong, Macao and Taiwan
HTDZs	High-Tech Development Zones
IC	Industrial Classification
ICNEA	Industrial Classification for National Economic Activities
ICT	Information and Communication Technology
IIS	Independent Innovation Strategy
LMEs	Large- and Medium-sized Enterprises
MNCs	Multi National Corporations
MOF	Ministry of Finance
NIS	National Innovation System
NBS	National Bureau of Statistics
PIM	Perpetual Inventory Method
R&D	Research and Development
SNA	System of National Accounts
S&T	Science and Technology
S&T Guidelines	"National Guidelines on a Medium- and Long-term Programme for Science and Technology Development 2006-2020"
SOEs	State-owned Enterprises